

Intelligent and universal process and system for solid waste treatment

Technical field

The present invention relates to an intelligent and universal method and process for treating different types of solid waste. The method and process disclosed herein reduce total content and the leachable portion of heavy metals, organic pollutants, and soluble salts in the solid waste and makes the treated solid waste safer for disposal or more suitable for reuse.

Background of the invention

Globally, humans generate billions of tons of waste annually. In particular, among the wastes generated each year, a significant portion is solid waste. The vast generation of solid waste presents serious consequences, including rapid exhaustion of waste storage space in landfills, environmental degradation and pollution, adverse impacts on public health, and sometimes geopolitical tensions. In addition, to address the dual problems of rising waste generation volume and rising materials cost, governments are seeking to convert at least some solid waste into materials or useful products for resource recovery in order to substantially reduce final waste volume and to rely less on raw materials.

Incineration bottom ash

The incineration of municipal solid waste produces solid residues that are collected at the bottom of the incinerator and they are referred to as incineration bottom ash (IBA). IBA makes up about 90% of all solid residues generated during the incineration process and is mainly composed of glass, ceramics, magnetic metals, and unburned organic matters. Since IBA has similar physical and chemical properties as secondary aggregates for civil engineering and construction, it is often used as materials in road construction or other construction industries.

Incineration fly ash

Municipal solid waste incineration fly ash (IFA) is a type of municipal solid waste incineration ash that is typically removed from exhaust flue gases during incineration. Compared to IBA, IFA is more hazardous and direct landfill of IFA can raise severe environmental contamination concerns. In some countries, an approach of IFA disposal involves dilution with less toxic IBA. However, as IBA can be potentially used as construction materials, this approach become less practicable.

Sewage sludge

Sewage sludge is the main by-product from the process of wastewater treatment and is another waste that deserves concern. Generally, sewage sludge contains several harmful substances, such as pathogens, heavy metals, and organic contaminants, which could be harmful to the environment as well as humans. Typical sewage sludge disposal practices include land-spreading and landfilling. However, governments have tightened restrictions on land-spreading of sewage sludge due to public concerns about pathogen transfer to crops and accumulation of heavy metals in agricultural soils. Also, in some countries, the types of sewage sludge that can be landfilled are limited, because

of the concerns of methane generation under anaerobic conditions. The presence of heavy metals and organic contaminants hampers extensive composting and agricultural use of the sewage sludge. Nevertheless, the treatment of sewage sludge can allow the sludge to be disposed of more safely.

Sewage sludge incineration ash

Incineration is another widely used process to deal with sewage sludge till today. In some Asian and European countries, sewage sludge is incinerated because of limited available land or local restriction against land application and landfilling of sludge. Incineration of sewage sludge decomposes organic matter in sewage sludge. However, a considerable amount of sewage sludge incineration ash still remains. The most common industrial application for sewage sludge ash is to use it as fillers in brick or cement block production. However, sewage sludge incineration ash, at least in large quantities, is not especially suitable for reuse in construction materials due to the large portion of heavy metals in sewage sludge incineration ash.

Wastewater treatment sludge

Wastewater treatment sludge is a byproduct of wastewater treatment process. It may contain coagulants used during the wastewater treatment process, heavy metals, and organic compounds. Current common management practice is to dispose of wastewater treatment sludge in landfills. This is due to the high concentrations of heavy metals in the wastewater treatment sludge that make other management options less appealing.

Slags

Slags are byproducts of metal production and they contain large amounts of heavy metals. The leaching of some heavy metals can cause environmental concerns. Nevertheless, the immobilization or removal of heavy metals in the slags can also be used as an economical way to clean the slags to the point where they are not only safe for disposal but also may be used as products in construction. This is a viable alternative to the conventional method of slag disposal by dumping, which occupies land unproductively and sometimes causes water contamination.

Environmental standards

Waste and wastewater disposal and reuse standards protect the environment and human populations against exposures to heavy metals and other pollutants. In biological systems, heavy metals have been reported to be associated with adverse effects in cellular organelles, cell membranes, mitochondria, lysosomes, endoplasmic reticulum, nuclei, and important enzymes. Heavy metal ions can interact with cell components, such as DNA and nuclear proteins, causing damage and structural changes that lead to carcinogenesis or apoptosis. According to the U.S. Environmental Protection Agency, some heavy metals are classified as either “known” or “probable” human carcinogens based on current epidemiological and experimental studies. In establishing disposal and reuse standards for wastes, risk assessment is conducted by regulatory bodies to promulgate rules to protect the environment and human health. Therefore, solid waste treatment outcomes are often compared to the criteria values in the applicable standard to determine compliance with disposal or reuse regulations. Examples of applicable standards that are cited are China’s type I common industrial solid waste standard, Singapore’s acceptance criteria for landfill disposal, and

the Danish waste-to-resource standard from Statutory Order No. 1662 of 2010. Depending on the particular environmental standards that are set by a local authority, the criteria could be very stringent and meeting such criteria for solid waste disposal or reuse remains a challenge.

Artificial intelligence

Artificial intelligence technology uses computer systems and programs that can mimic human capabilities, such as problem solving, learning, perception, understanding, reasoning, and awareness of surroundings. Advanced computer models have been used to study climate patterns to forecast weather and predict air pollution levels. In recent years, artificial intelligence has also been used in monitoring characteristics of water contamination, waste sorting, determining waste collection truck routes, etc. Therefore, the technology holds potential to improve efficiency, and perhaps effectiveness or accuracy, of solid waste treatment, environmental management, and risk assessment.

Solid materials reuse

The vast generation of solid waste results in the occupation of precious land resource, and possibly causes soil, water, and air pollution. Therefore, increasing the usage rate of major solid waste is a priority. Current common approaches include producing construction materials, constructing roadbeds, and backfilling mined out areas.

Patent literature

Patent CN103274658B, filed by Yu Kefu et al in 2013, describes a method for hazardous waste recycling wherein mixing and blending, pH monitoring, grinding, addition of acidic and alkaline sludge, and material pressing steps. The method is not a universal treatment method for wastes, and there is no intelligent component that can automatically adjust treatment parameters to fit the particular needs of the practitioner.

Patent US20150324760A1, filed by Ultra Smart Recycling LLC in 2015, describes a smart waste management device and system. However, the manner of management is only for tracking, not for abatement of environmental pollutants.

Summary of the invention

Summary of invention

Throughout this specification and beyond, unless the context requires otherwise, “comprise,” or variations such as “comprises” or “comprising,” shall be understood to imply the inclusion of a stated component or components or integrated components but not the exclusion of any other components. In addition, as they appear in the specification and claims, the singular forms “a,” “an,” and “the” include the plural referents unless otherwise stated.

The present invention has been accomplished under a context described in previous sections. It is, therefore, the main objective of the present invention to provide a system and method for treating solid waste, such as IBA, IFA, sludge, and slag for safe disposal and/or reuse. To achieve these and similar objectives of the present invention, the system for treating solid waste comprises:

- a) A computing processing unit that processes current treatment information and executes appropriate treatment steps;
- b) A unit that performs drying function;
- c) A unit that performs particle size sieving function;
- d) A treatment chamber housing washing, ultrasonication, and scum removal functions;
- e) A chemical immobilization component;
- f) A magnetic separator and an eddy current separator;
- g) A sensor network and algorithm system that continuously monitors the concentrations of pollutants including soluble salts, heavy metals, and organic pollutants, and feeds the information to the computing processing unit for treatment decision making;
- h) A wastewater treatment unit; and
- i) A post-treatment solid waste particle re-composition unit.

Problems solved by the invention

The amount of solid wastes generated in the world is staggering. Conventional management practice of solid wastes is to landfill them. However, this is unsustainable because landfilling will require occupying of more dwindling habitable space. In addition, untreated solid wastes, especially those that are hazardous, that are landfilled may cause environmental pollution threatening ecosystems, wildlife, and public health. A few solid waste treatment technologies have been studied, including simple washing, thermal treatment, and chemical methods. However, few of these technologies can universally treat different solid wastes to meet the stringent reuse standards of some countries at a reasonable cost.

Means for solving the problems

The system described in the present invention provides an intelligent and universal treatment solution for solid wastes, including, but not limited to IBA, IFA, sewage sludge, sewage sludge incineration ash, wastewater treatment sludge, and slags. The treatment system comprises different components that can automatically switch on depending on the treatment of particular waste type and landfill or reuse standards to meet. The different components include dryer, crusher, sieve, washing unit, ultrasonicator, chemical immobilization and/or decomposition, scum remover, wastewater treatment, magnetic separator, eddy current separator, and re-composition unit. The present invention also includes a process of operating the system, which can maximize the treatment efficacy to meet landfill or reuse standards. In particular, the treatment process uses a sensor network to measure real-time treatment process parameters such as pH and pollutant concentrations, and sends this information to the computing processing unit to control and finetune treatment parameters, such as washing liquid volume and/or chemical immobilization and/or decomposition agent dosage, for the final treated solid waste to meet desired landfill and/or reuse criteria. The treatment process also includes a treatment information gathering and archiving by artificial intelligence to collect treatment information to optimize the current treatment process and improve future treatment process for solid wastes.

Advantages of the invention

Other solid waste treatment systems can only treat one type of waste, or they may consist of different systems, each of which can treat one type of waste. The present invention is a universal treatment system that treats all types of solid wastes in one system, with different units or components switched on or off depending on the waste type as well as landfill or reuse standard. Compared to other treatment approaches that prescribe a different treatment system for a different waste type, the present invention confers advantages of compact design, space saving and low cost. In addition, the various components of the treatment system can be tightly packed to be fitted inside a freight container for easy deployment for on-site waste treatment purposes.

The sensor network of the present invention measures treatment process parameters, such as pH and pollutant concentrations and sends the information to the computing processing unit to control and finetune treatment system parameters such as washing liquid volume and chemical immobilization and/or decomposition agent dosage to make the final treated solid waste meet applicable environmental standards. The sensor network works together with artificial intelligence technology to gather information about treatment effectiveness and devises optimal treatment system and process parameters for future more waste types in the future. The artificial intelligence technology takes factors including but not limited to waste type, waste source, geographic origin of solid waste into consideration. With the accumulated information and experiences, the artificial intelligence system of the present invention builds a solid waste treatment library that can guide and instruct future treatments. This sensor network and artificial intelligence technology offer advantages of reduced time required for waste treatment optimization and testing for quality control purposes and of enabling non-experts to operate the treatment system.

Another novelty feature of the present invention is the skimmer. In a conventional treatment without skimmer for scum removal, excessive scum formation in the treatment system disrupts solid waste treatment, and thus the treatment effectiveness and efficiency decrease. Scum removal significantly improves treatment effectiveness and efficiency by reducing equipment downtime for maintenance and cleaning.

Typical systems treat solid waste for landfill. Solid waste disposal in landfill as a final solution is not sustainable due to limited land resources and demand of natural raw materials. The process and system described in the present invention enable the treated waste materials to be used in different applications including, but not limited to, nonstructural concrete and road construction material. To improve waste utilization outcome, the treatment process is complemented by a magnetic separator and eddy current separator that recover ferrous and non-ferrous metals that may otherwise hinder waste material application as construction materials.

Brief description of the drawing

The invention as described graphically in an exemplary manner, without restricting the general intent of the invention including but not limited to the particular configuration, shape, and scale of any of the elements in the drawing, based on exemplary embodiments in reference to the drawing, whereby the schematic drawing is expressly referred to for the disclosure of all details according to the invention that are not explained in greater detail in the text.

FIG. 1 is an overview of the solid waste treatment system.

FIG. 2 shows the treatment components switched on for type A waste treatment.

FIG. 3 shows the treatment components switched on for type B waste treatment.

FIG. 4 shows the treatment components switched on for type C waste treatment.

FIG. 5 shows the treatment components switched on for type D waste treatment.

Detailed description of the preferred embodiments

Best mode for carrying out the invention

The object of the present invention is an intelligent and universal solid waste treatment system and process that utilize a sensor network with feedback loop to ensure compliance with set environmental criteria and artificial intelligence that collects information about each treatment outcome to devise and implement treatment for more waste types in the future. It is the main objective of the present invention to treat solid wastes including, but not limited to IBA, IFA, sewage sludge, sewage sludge incineration ash, wastewater treatment sludge, slags for safe disposal and/or reuse. The heavy metals and organic pollutants that are immobilized or decomposed and salts that are washed off by the treatment method of the present invention include, but are not limited to, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, silver, selenium, tin, zinc, total organic carbon (TOC), chemical oxygen demand (COD), sodium, bromide, chloride, fluoride, and sulfate. Treatment by the present invention is beneficial for solid waste utilization in civil engineering applications since the high soluble salts content can corrode steel structures and negatively affect the hardening and strength of concrete. After washing, chemical stabilization of the heavy metals in the washed solid waste can be achieved using some heavy metal immobilization agents, and organic pollutants can be decomposed by oxidation agents.

The preferred embodiment of the treatment system of the present invention comprises the following components that work together in synergy:

- a) A computing processing unit that processes current treatment information and executes appropriate treatment steps;
- b) A unit that performs drying function;
- c) A unit that performs particle size sieving function;
- d) A treatment chamber housing washing, ultrasonication, and scum removal functions;
- e) A chemical immobilization and/or decomposition component;
- f) A magnetic separator and an eddy current separator;
- g) A sensor network and algorithm system that continuously monitors the concentrations of pollutants including soluble salts, heavy metals, and organic pollutants, and feeds the information to the computing processing unit for treatment decision making;
- h) A wastewater treatment unit; and

- i) A post-treatment solid waste particle re-composition unit.

The different components of the system are switched on or off automatically for a given waste type and environmental criteria. For example, solid wastes that are dry do not need drying unit to be switched on by the treatment system. Other sources of information that inform the computing processing unit and artificial intelligence technology include further characteristics of the waste, the state of treatment, and the compliance standards.

The computing processing unit stores archive of treatment method information and adopts artificial intelligence technology to determine the best course of treatment and to execute instructions for treatment procedures based on the information about the solid waste and specific environmental and/or material utilization standards and guidelines.

The treatment chamber is the main component that carries out the treatment work following instructions from the computing processing unit.

The scum remover mechanically removes scum generated inside the treatment chamber and directs the scum away from the treatment chamber. This greatly improves overall treatment efficiency.

The sensor network (not shown in the figures) that continuously monitors the concentrations of pollutants including soluble salts, heavy metals, and organic pollutants and feeds the information to the computer processing unit for automatic treatment parameter adjustments.

The solid waste particle re-composition unit distributes treated solid waste particles according to weight proportions of each size fraction which are required for different purposes and applications as determined by the computer processing unit.

The solid waste being introduced into the system is classified into types. For example, the solid wastes can be classified into A to D such that A is IBA with material heterogeneity and particle size distribution approximately 50 mm to below 1 mm, B is powdery or consists of lumps of powdery material and has particle size distribution below 1 mm, C has moisture content 40% to 70% and particle size distribution approximately 60 mm to below 1 mm, and D is harder particles having particle size distribution below 30 mm and the particle sizes are relatively uniform.

Solid wastes that are too wet for optimal treatment are dried. For example, type B and C materials are dried to have maximum moisture content of 30% to 40%. Type A and D materials do not need drying for the process disclosed herein.

Sieving of solid particles achieves two main purposes. First, it separates particles by size to allow for optimal pollutant stabilization for each size fraction. Second, it splits the particles for more efficient re-composition according to required proportions for a particular usage scenario as determined by the processing unit. For IBA, i.e. type A, and other wastes with wide particle size distribution, particles are separated into fine, medium, and coarse fractions, where fine particles are below 3 mm, medium-sized particles are 3 to 20 mm, and coarse particles are 20 to 50 mm.

The main treatment chamber houses the washing, ultrasonication, and scum remover functions. The following describe the components of the treatment chamber:

- The washing liquid of washing function is water, an aqueous solution of inorganic acid, an aqueous solution of an organic acid, a complexing agent, and combinations thereof; the inorganic acid is hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid and combinations thereof; the organic acid is citric acid, oxalic acid, or acetic acid, and combinations thereof; and complexing agent is ethylenediaminetetraacetic acid, ethylenediamine-N,N'-disuccinic acid, nitrilotriacetic acid, ethylenediamine, dimercaprol, ammonium citrate, and combinations thereof.
- Ultrasonication helps separate fine and ultrafine particles from coarse particles with efficiency. The frequency of the ultrasonication system can be set from 0.1 to 85 MHz.
- The scum remover mechanically removes scum formed during the washing step and diverts it away from the treatment equipment.

The chemical dosing system within the main treatment chamber adds the optimum chemical immobilization and/or decomposition agents. The agents are selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof.

The sensor network connects the main treatment chamber to the computing processing unit to feed the latter information about the state of treatment, including concentrations of environmental pollutants and harmful substances. This helps the computing processing unit automatically adjust the volume of washing liquid, and other treatment system and process parameters, until concentrations of environmental pollutants and harmful substances are below safety or environmental standard criteria limits.

The wastewater treatment unit comprises a flocculating or coagulating step using a chemical that is selected from the group consisting of aluminum sulfate, ferric chloride, ferric sulfate, ferrous sulfate, polyacrylamide, polyaluminum chloride, polyaluminum chlorosulfate, polyaluminum silicatesulfate, sodium alginates, polyelectrolytes, and combinations thereof.

The re-composition unit mixes treated solid waste particles in certain proportions by weight according to different usage scenarios. For groups A and D, the solid particle re-composition unit reassembles the treated solid waste particles such that coarse particles are 2 to 20 mm and fine particles are <2 mm, and treated coarse particles of 2 to 20 mm in size substitute 5% to 50% of stones and fine particles of size <2 mm substitute 10% to 50% of sand in concrete marking formulation. For group B, treated solid particles may substitute 1% to 5% of sand in concrete formulation, or the treated solid particles may be safely disposed. For group C, the solid particle re-composition unit separates treated solid waste particles that are of size <2 mm to substitute 5% to 10% of sand in concrete making formulation. If the particular treated solid waste is not to be used in an application, subject to the discretion of the end-user or operator or owner, the treated solid waste may be disposed of provided that it meets the safe disposal criteria.

The different components of the treatment system sufficiently compact to be fitted in a freight container for facilitating on-site deployment.

FIG. 1 shows the schematic of a system for treatment of solid wastes.

It will be apparent that further modifications and combinations of modifications of the described method may be practiced as well. For example, in method of FIG. 1 and any mentioned variations, sieving may take place simultaneously with washing, or the treatment configuration is such that the treatment chamber treats each solid waste particle partition separately in the same treatment chamber but in time-staggered manner or in different lines of treatment chamber.

The solid waste being introduced into the system is classified into types A to D such that A is IBA with material heterogeneity and particle size distribution approximately 50 mm to below 1 mm, B is powdery or consists of lumps of powdery material and has particle size distribution below 1 mm, C has moisture content 40% to 70% and particle size distribution of approximately 60 mm to below 1 mm, and D is harder particles having particle size distribution below 30 mm and the particle sizes are relatively uniform.

Solid wastes that are too wet for optimal treatment are dried in **1**. For example, type B and C materials are dried to have maximum moisture content of 30% to 40%. Type A and D materials do not need drying for the process disclosed herein.

Mechanical crusher or crumbler **2** reduces size of solid waste particles that are too bulky for treatment.

Sieving of solid particles **3** achieves two major purposes. First, it separates particles by size to allow for optimal pollutant stabilization for each size fraction. Second, it splits the particles for re-composition according to suitable proportions for a particular usage scenario as determined by the processing unit. For IBA, and other wastes with wide particle size distribution, particles are separated into fine, medium, and coarse fractions, where fine particles are below 3 mm, medium-sized particles are 3 to 20 mm, and coarse particles are 20 to 50 mm.

The main treatment chamber **4** houses the washing, ultrasonication, and scum removal components.

Washing of solid waste particles is performed with a washing liquid. The washing liquid is water, an aqueous solution of inorganic acid, an aqueous solution of an organic acid, a complexing agent, and combinations thereof, the inorganic acid is hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid, and combinations thereof, the organic acid is citric acid, oxalic acid, or acetic acid, and combinations thereof, and complexing agent is ethylenediaminetetraacetic acid, ethylenediamine-N,N'-disuccinic acid, nitrilotriacetic acid, ethylenediamine, dimercaprol, ammonium citrate, and combinations thereof.

Ultrasonication helps efficiently separate fine and ultrafine particles from coarse particles. The frequency of the ultrasonication system can be set from 0.1 to 85 MHz.

The sensor network (not shown in figures) connects the main treatment chamber to the processing unit to feed the latter information about the treatment status, including real-time pH value, and concentrations of environmental pollutants and harmful substances. This helps the processing unit automatically adjust the volume of washing liquid, and other treatment system and process parameters, until concentrations of environmental pollutants and harmful substances are below safety limits.

The scum removal step mechanically removes scum generated in the treatment chamber. Scum removal substantially improves treatment efficiency. The wastewater treatment step **5** comprises a flocculating or coagulating step using a chemical agent that is selected from the group consisting of aluminum sulfate, ferric chloride, ferric sulfate, ferrous sulfate, polyacrylamide, polyaluminum chloride, polyaluminum chlorosulfate, polyaluminum silicatesulfate, sodium alginates, polyelectrolytes, and combinations thereof.

Magnetic separator **6** and eddy current separator **7** recover ferrous and non-ferrous particles from the solid waste particles, respectively. Recovery of metals not only saves valuable metal resources, but also helps maintain structural integrity of treated solid waste particles when they are used as construction materials.

Chemical immobilization **8** applies immobilization and/or decomposition agents to chemically immobilize and/or decompose heavy metals and organic pollutants in the solid waste particles. The agents are selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof.

Re-composition **9** mixes treated solid waste particles in certain proportions by weight according to different reuse **10** scenarios. For groups A and D, the solid particle re-composition unit reassembles the treated solid waste particles such that coarse particles are 2 to 20 mm and fine particles are <2 mm, and treated coarse particles of 2 to 20 mm in size substitute 5% to 50% of stones and fine particles of size <2 mm substitute 10% to 50% of sand in concrete marking formulation. For group B, the treated solid waste particles that are <2 mm may substitute 1% to 5% of sand in concrete formulation, or the treated solid particles may be disposed. For group C, the solid particle re-composition unit separates the treated solid waste particles that are of size <2 mm to substitute 5% to 10% of sand in concrete making formulation. The treated waste may also be disposed of in landfill **11** without being reused.

Examples

Example 1: Treatment of incineration bottom ash

A representative IBA was collected at a municipal solid waste incineration plant. The IBA with mass 5,000 kg per batch was to be treated. The computing processing unit was switched on for inputting in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the crusher, sieve, washing, ultrasonication, skimmer, wastewater treatment, magnetic separator, eddy current separator, chemical immobilization, and re-composition units were automatically switched on, while the other units were automatically switched off. The IBA was first crushed to below 50 mm and then underwent size separation by sieving to achieve separated particles of fine (< 2 mm), medium (2 to 30 mm), and coarse (> 30 mm) sizes. Distilled water with a volume of 50,000 liters was used for washing. The ultrasound frequency of treatment was set at 10 MHz.

During the treatment process, an amount of 5 wt. % H_2O_2 (50 wt. % aqueous solution) based on the weight of IBA was added 5 minutes before the start of treatment, and an amount of 1 wt. % Na_2S solid based on the weight of IBA was added 15 minutes before the completion of treatment. The total treatment time excluding wastewater treatment was 20 minutes. For the treatment of

wastewater, the pH of the wastewater was adjusted to 8 with 50% (v/v) H₂SO₄ monitoring by a pH sensor, and then the wastewater sludge was allowed to be settled and filtered. Subsequently, the untreated and treated IBA samples were subjected to leaching and analytical tests to verify the treatment efficiency. The employed leaching test method was a batch leaching method that is specified in British Standard EN 12457-1:2002 (British Standards Institution), which is hereby incorporated by reference. The leachates were analyzed, as described in Standard Methods for the Examination of Water and Wastewater that is published by the American Public Health Association (APHA), by inductively coupled plasma-mass spectrometry (ICP-MS) for metals and metalloids including antimony, arsenic, barium, cadmium, chromium (total), cobalt, copper, manganese, mercury, molybdenum, nickel, lead, silver, selenium, tin, and zinc; by inductively coupled plasma-optical emission spectrometry (ICP-OES) for sodium; by ion chromatography for bromide, chloride, and sulfate; by ion-selective electrode for fluoride; by flow injection analyzer for ammonia; by Kjeldahl nitrogen analyzer for total nitrogen; and by total organic carbon (TOC) analyzer for TOC. chromium (VI) concentration in the leachates was analyzed by liquid chromatography-ICP-MS (LC-ICP-MS) as per EN71-3:2012. Total phosphorus and chemical oxygen demand (COD) concentrations in the leachates were analyzed by digestion method that is described by the HACH 8190 method and colorimetric method that is described by the HACH 8000 method, respectively; both are published by the Hach Chemical Company. All testing results were inputted to the computing processing unit. With the machine-learning program, the artificial intelligence system auto-modified the treatment process for treating the next batch of IBA.

As shown in Table 1, concentrations of all contaminants decreased after treatment with the system and process described herein. Compared with the results before machine-learning, the contaminant concentrations were greatly decreased by using machine-learning program.

Table 1: Incineration bottom ash treatment outcome

Contaminants	Test method	Before treatment (mg/kg)	After treatment without machine learning (mg/kg)	After treatment with machine learning (mg/kg)
Antimony	APHA 3120B	<0.002	<0.002	<0.002
Arsenic		0.00533	0.00531	<0.004
Barium		0.74	0.69	0.49
Cadmium		0.006907	0.004735	0.0009
Chromium (total)		0.2140	0.1054	0.009152
Chromium (VI)	EN71-3:2012	0.285	<0.05	<0.05
Cobalt	APHA 3120B	0.01137	0.007811	0.008946
Copper		13.72	3.65	0.03658
Manganese		0.007839	0.006773	0.005381
Mercury	APHA 3125B	0.000128	0.000127	0.000103
Molybdenum	APHA 3120B	1.7394	1.5863	0.2108
Nickel		0.4653	0.3659	0.0067
Lead		0.9355	0.8635	<0.002
Sodium		2576	548	128.5
Silver		0.00049	0.00039	0.00025
Selenium		<0.004	<0.004	<0.004
Tin		<0.004	<0.004	<0.004
Zinc		0.3562	0.0869	0.0574
Bromide (Br ⁻)	APHA 4110B	43.83	2.59	<0.2
Chloride (Cl ⁻)		9249	136	37
Fluoride (F ⁻)	APHA 4500-F (C)	1.84	0.92	0.76
Sulfate (SO ₄ ²⁻)	APHA 4110B	2641	368	143
Ammonia (as N)	APHA 4500-NH3 (H)	2.5	1.3	0.5
Total Nitrogen (as N)	APHA 4500-N (C)	47.0	27.4	2.45
Total Phosphorus (as P)	Hach 8190	0.41	0.38	0.096
Total Organic Carbon (TOC)	APHA 5310B	872	127	53
Chemical Oxygen Demand (COD)	Hach 8000	2316	1249	182

The treatment of IBA was also performed with skimmer switched on and off. The treatment effect with regard to pollutant concentrations was about the same with the skimmer switched on or off. However, when the skimmer was switched off, treatment efficiency decreased up to two times compared to when the skimmer was switched on. This is due to system disruption caused by excessive scum generated.

The re-composition unit sorted the treated solid waste particles such that 100% of particles are <75 mm, 85% of particles are <37.5 mm, 45% of particles are <10 mm, 25% of particles are <5 mm, 8% of particles are below 0.6 mm, and 0% of particles are <0.075 mm; the sorted and treated solid waste particles according to the system and process are to be used as road sub-base materials.

Example 2: Treatment of wet and dry incineration fly ash

A representative IFA was taken at a fabric filter unit within the air pollution control systems inside a municipal solid waste incineration plant. Each batch of IFA with a mass of 3,000 kg was to be treated. The computing processing unit was switched on for typing in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the crusher and chemical immobilization were switched on, while the other units were switched off. In addition, the drying unit was switched on for wet IFA treatment and off for dry IFA treatment. For drying of IFA, the temperature was 35°C and the drying duration was 48 hours. Chemical immobilization agent NaHS solid was added at a dosage of 0.5 wt. % based on the dry weight of IFA at 3 minutes before completion of treatment. The untreated wet and dry IFA and treated wet and dry IFA samples were tested according to toxicity characteristic leaching procedure (TCLP) set forth in the United States Federal Register, Vol. 55, No. 126, pp. 26985-26998 (June 29, 1999), which is hereby incorporated by reference. The leachates were analyzed by ICP-OES for barium and sodium and by ICP-MS for arsenic, cadmium, chromium (total), copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc. Anions, including chloride and fluoride were analyzed by ion chromatography.

As shown in Table 2, only lead concentration in untreated wet and dry IFA failed Singapore's acceptance criteria for landfill disposal. After treatment with the system and process described herein, the concentration of lead was decreased and met the landfill criteria.

Table 2: Incineration fly ash treatment outcome

Contaminants	Wet IFA before treatment (mg/L)	Dry IFA before treatment (mg/L)	Wet IFA after treatment (mg/L)	Dry IFA after treatment (mg/L)	Singapore acceptance criteria for landfill disposal (mg/L)
Arsenic	<0.004	<0.004	<0.004	<0.004	5
Barium	3.53	3.61	0.93	0.82	100
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	1
Chloride (Cl ⁻)	11170	11283	2705	2603	Not regulated
Chromium (total)	0.1231	0.1329	0.0083	0.0035	5
Copper	0.2285	0.2397	<0.0004	<0.0004	100
Fluoride (F ⁻)	4.16	4.96	1.85	1.72	150
Iron	0.0043	0.0041	0.0021	0.0016	100
Lead	39.86	48.17	<0.0005	<0.0005	5
Manganese	<0.0001	<0.0001	<0.0001	<0.0001	50
Mercury	0.013	0.021	0.00008	0.00006	0.2
Nickel	<0.005	<0.005	<0.005	<0.005	5
Selenium	<0.002	<0.002	<0.002	<0.002	1
Sodium	912	973	215	198	Not regulated
Silver	0.00337	0.00427	0.00005	0.00003	5
Zinc	8.0925	8.1373	0.4168	0.3808	100

After treatment, the IFA was sent for landfill disposal.

Example 3: Treatment of sewage sludge incineration ash

Representative sewage sludge incineration ash was taken from a waste incineration plant. Each batch of sewage sludge incineration ash with a mass of 5,000 kg was to be treated. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the chemical immobilization and re-composition units were switched on, while the other units were switched off. Chemical immobilization agent NaHS solid was added at a dosage of 0.2 wt. % based on the weight of sewage sludge incineration ash 3 minutes before completion of treatment. The untreated and treated sewage sludge incineration ash samples were tested according to TCLP. The leachates were analyzed by ICP-OES for barium and by ICP-MS for arsenic, antimony, cadmium, chromium, copper, lead, mercury, nickel, and selenium. All the testing results were inputted to the computing processing unit. With the machine-learning program, the artificial intelligence system auto-modified the treatment process for treating the next batch of sewage sludge incineration ash.

According to Table 3, the treated sewage sludge incineration ash leachate was able to meet the WHO drinking water criteria, a very stringent set of criteria to meet. This demonstrates the capability of the current invention to meet very stringent environmental standard criteria. Compared

with the results before machine-learning, the element concentrations were greatly decreased by using machine-learning program.

Table 3: Sewage sludge incineration ash treatment outcome

Element	Before treatment (mg/L)	After treatment without machine-learning program (mg/L)	After treatment with machine-learning program (mg/L)	WHO drinking water standard (mg/L)
As	ND	NA	ND	0.01
Ba	0.1425	0.1137	0.0083	1.3
Cd	0.0198	0.0092	0.0004	0.003
Cr	0.0051	0.0036	0.0002	0.05
Cu	1.4586	0.8079	0.1373	2
Hg	0.00040	0.00001	0.00001	0.006
Ni	0.1153	0.0475	0.0075	0.07
Pb	ND	ND	ND	0.01
Sb	0.0445	0.0167	0.0047	0.02
Se	0.1357	0.0073	0.0026	0.04

At the treated solid waste re-composition stage, the treated solid waste particles that were above the size of 0.2 mm were separated and those below 0.2 mm are sent for mixing with cement in a treated sewage sludge incineration ash:cement ratio of 1:10.

Example 4: Treatment of sewage sludge

A representative sample of sewage sludge was obtained from a wastewater treatment plant. Each batch of sewage sludge with a mass of 2,000 kg was to be treated. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the drying, crusher, chemical immobilization, and re-composition units were switched on, while the other units were switched off. The sewage sludge was dried to from 98 % to 50% moisture content with a thermal process (65°C). The thermal process not only dried the sewage sludge, but also eliminated the pathogens. During the treatment process, an amount of 0.5 wt. % H_2O_2 (50 wt. % aqueous solution) based on the weight of the dried sewage sludge was added at 10 minutes before start of treatment, and an amount of 1 wt. %, NaHS solid based on the weight of dried sewage sludge was added 15 minutes before completion of treatment. The treatment time of the sewage sludge was set at 30 minutes. The untreated sewage sludge and treated sewage sludge samples were tested according to TCLP. The leachates were analyzed by ICP-MS for heavy metals. All the testing results were inputted to the computing processing unit. With the machine-learning program, the artificial intelligence system auto-modified the treatment process for treating the next batch of sewage sludge.

As shown in Table 4, compared with the results before machine-learning, the contaminant concentrations were greatly decreased by using machine-learning program. With the machine-learning program, the concentrations of arsenic, cadmium, chromium (total), copper, lead, nickel, and zinc could all meet China's type I common industrial solid waste standard after treatment.

Table 4: Sewage sludge treatment outcome

Contaminants	Before treatment (mg/L)	After treatment without machine-learning program (mg/L)	After treatment with machine-learning program (mg/L)	China type I common industrial solid waste standard (mg/L)
Arsenic	6.027	0.479	0.328	0.5
Cadmium	2.186	0.094	0.057	0.1
Chromium (total)	5.114	1.7	0.509	1.5
Copper	7.903	0.351	0.172	0.5
Lead	16.4	0.569	0.196	1
Nickel	2.709	0.802	0.136	1
Zinc	3.16	1.860	0.268	2

The treated sewage sludge was disposed as a nonhazardous waste to landfill.

Example 5: Treatment of industrial slag

Representative industrial slag was collected from a steel manufacturing factory. Each batch of industrial slag with a mass of 2,500 kg was to be treated. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the crusher, washing, ultrasonication, skimmer, wastewater treatment, chemical immobilization, and re-composition units were switched on, while the other units were switched off. In addition, the artificial intelligence technology was switched on for typical daily operation. The volume of 0.1% (v/v) sulfuric acid aqueous solution was 5,000 liters for washing. The chemical immobilization agent Na_2S powder at dosage 0.3 wt. % based on the weight of the industrial slag was added 5 minutes before the washing was about to be completed. The ultrasound frequency was 20 kHz and the treatment time was set at 10 minutes excluding wastewater treatment. For wastewater treatment, the pH was adjusted to 7 with 80% (v/v) H_2SO_4 monitoring by a pH sensor, followed by addition of flocculants and sedimentation. The leaching characterization method was batch leaching method BS EN 12457-2:2002. The leachates were analyzed by ICP-OES for barium, and ICP-MS for chromium, copper, lead, selenium, and zinc. All the testing results were inputted to the computing processing unit. With the machine-learning program, the artificial intelligence system auto-modified the treatment process for treating the next batch of industrial slags.

As shown in Table 5, the concentrations of barium, chromium, copper, lead, selenium, and zinc could meet the Danish waste-to-resource standard after treatment with machine-learning program. However, without machine-learning program, the concentration of chromium could not meet the Danish waste-to-resource standard.

Table 5: Industrial slag treatment outcome

Contaminants	Before treatment (mg/kg)	After treatment without machine-learning program (mg/kg)	After treatment with machine-learning program (mg/kg)	Category 1 and 2 of Danish Waste-to-Resource Standard (mg/kg)
Barium	34.8	1.37	1.02	24
Chromium	0.0407	3.68	<0.0002	2.8
Copper	0.00923	0.0731	<0.0004	2.8
Lead	0.906	0.242	<0.0005	0.45
Selenium	0.1205	0.0826	<0.002	0.11
Zinc	0.0703	0.0304	<0.0002	6.6

Example 6: Treatment of contaminated soil

A representative contaminated soil sample was obtained from a former mining site. Each batch of contaminated soil with mass of 6,000 kg was to be treated. As this contaminated soil was sandy material similar to slag in physical features, it was classified as group D waste type. In this example, treatment of contaminated soil sample from one area of the mining site was performed after being informed by past slag treatment information stored in the library. Treatment was then performed on a contaminated soil sample from a second, different, mining site area and this treatment performed after the machine-learning from the treatment results of contaminated soil from the first mining area. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the washing, ultrasonication, skimmer, wastewater treatment, chemical immobilization, and re-composition units were switched on, while the other units were switched off. The volume of 0.05% (v/v) sulfuric acid aqueous solution was 6,000 liters for washing. The chemical immobilization agent Na_2S powder at dosage 0.3 wt. % based on the weight of the contaminated soil was added at 5 minutes before the washing was about to be completed. The ultrasound frequency was 20 kHz and the treatment time was set at 10 minutes excluding wastewater treatment. For wastewater treatment, the pH was adjusted to 7 using 80% (v/v) H_2SO_4 monitoring by a pH sensor, followed by the addition of flocculants and sedimentation. The leaching characterization method was BS EN 12457-2:2002. The leachates were analyzed by ICP-MS for cadmium, chromium, and lead, selenium.

Treatment results are shown in Table 6. The treatment scheme of contaminated soil informed by previous slag treatment showed effective reduction of concentration of chromium and lead, as was the case for slag treatment using the current treatment system. However, the concentration of cadmium still exceeded the regulatory level after treating contaminated soil sample from the first mining area based on slag treatment information. After the treatment of contaminated soil from a second contaminated site area based on treatment information of contaminated soil from the first site area, the concentration of cadmium met the regulatory level. This suggests that the artificial intelligence technology with the machine-learning program improved its treatment plan for contaminated soil after gathering treatment information from contaminated soil treatment as opposed to slag treatment.

Table 6: Contaminated soil treatment outcome

Contaminants	Before treatment (mg/kg)	After treatment of contaminated soil from first mining site area (mg/kg)	After treatment of contaminated soil from second mining site area (mg/kg)	China local standard (mg/kg)
Cadmium	28.4	1.26	0.85	1.0
Chromium	4.8	<0.0002	<0.0002	10.0
Lead	0.27	<0.0005	<0.0005	10.0

Treated contaminated soil was refilled at the original site.

Example 7: On-site treatment of sediment

A representative contaminated sediment sample was obtained from rural river downstream a plating factory that has since been closed. On-site treatment was desirable because the local authorities wished to save transportation costs and the treatment project was short term. Each batch of contaminated sediment with a mass of 3,000 kg was to be treated. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the drying, crusher, and chemical immobilization units were switched on, while the other units were switched off. The drying, crusher, and chemical immobilization units were fitted inside a freight container for easy deployment for on-site treatment. The sediment was dried to a moisture content of 45%. During treatment process, an amount of 0.2 wt. % H₂O₂ (50 wt. % aqueous solution) based on the weight of the sediment was added at 10 minutes before start of treatment, and an amount of 1 wt. % NaHS solid based on the weight of sediment was added at 15 minutes before completion of treatment. The treatment time of the sediment was set at 30 minutes. The leaching characterization method was BS EN 12457-2:2002. The leachates were analyzed by ICP-MS for heavy metals, and by ion chromatography for anions.

Treatment results are shown in Table 7. The contaminants of concern were copper, molybdenum, chloride, and sulfate. After treatment, the concentrations of all contaminants of concern met the local regulatory values.

Table 7: Contaminated river sediment treatment outcome

Contaminants	Before treatment (mg/kg)	After treatment of contaminated river sediment (mg/kg)	China local standard (mg/kg)
Copper	0.734	0.1573	2
Molybdenum	1.116	0.3731	0.5
Chloride	18.2	2.7	800
Sulfate	2005	618	1000

The treated sediment was diverted from landfilling for backfilling application.

Example 8: On-site treatment of wastewater treatment sludge

Representative wastewater treatment sludge was obtained from a semiconductor factory. The wastewater treatment sludge as from co-treatment of domestic and industrial wastewater. Each batch of wastewater treatment sludge with a mass of 2,000 kg was to be treated on-site. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the drying, crusher, and chemical immobilization units of the treatment system were switched on, while the other units were switched off. The drying, crusher, and chemical immobilization units were fitted inside a freight container for easy deployment for on-site treatment. On-site treatment of wastewater treatment sludge was desirable, because the semiconductor factory wished to save transportation costs and the treatment project was short term. The wastewater treatment sludge was dried to a moisture content of 40%. During the treatment process, an amount of 0.4 wt. % H₂O₂ (50 wt. % aqueous solution) based on the weight of the sludge was added 10 at minutes before start of treatment, and an amount of 0.7 wt. % NaHS solid based on the weight of sludge was added at 15 minutes before completion of treatment. The treatment time of the sludge was set at 30 minutes. The leaching characterization method was BS EN 12457-1:2002. The leachates were analyzed by ICP-MS for heavy metals, and by ion-selective electrode for fluoride.

Treatment results are shown in Table 8. The contaminants of concern were magnesium, manganese, and fluoride. After treatment, the concentrations of all contaminants of concern met the local regulatory values.

Table 8: Wastewater treatment sludge treatment outcome

Contaminants	Before treatment (mg/kg)	After treatment of wastewater treatment sludge (mg/kg)	China local standard (mg/kg)
Magnesium	124	0.182	NA
Manganese	0.52	0.036	0.3
Fluoride	14.7	1.3	4

The treated wastewater treatment sludge was disposed into inert waste landfill.

Example 9: On-site treatment of spent catalyst

A representative spent catalyst sample was obtained from a first petroleum refinery. Each batch of spent catalyst with mass of 1,500 kg was to be treated. As this spent catalyst was a wet powder similar to wet IFA in physical features, it was classified as group B waste type. In this example, treatment of spent catalyst from first petroleum refinery was performed after being informed by past IFA treatment information stored in the library. Treatment was then performed on a spent catalyst from a second, different, petroleum refinery and this treatment was performed by after the machine-learning from the treatment results of spent catalyst from the first petroleum refinery. The computing processing unit was switched on for keying in the waste type and environmental criteria. According to the guidelines from artificial intelligence system, the drying, crushing, and chemical immobilization units were switched on, while the other units were switched off. Chemical immobilization agent NaHS solid was added at a dosage of 0.5 wt. % based on the weight of spent catalyst at 3 minutes before completion of treatment. The untreated spent catalyst and treated spent

catalyst from the first and second petroleum refinery samples were tested according to TCLP. The leachates were analyzed by ICP-MS for heavy metals.

Treatment results are shown in Table 9. The treatment scheme of spent catalyst informed by previous IFA treatment showed effective reduction of concentration of some contaminants, namely arsenic, cadmium, copper, lead, manganese, and nickel, as was the case for IFA treatment using the current treatment system. However, concentrations of cobalt and selenium still exceeded the regulatory level after treating spent catalyst from the first petroleum refinery based on IFA treatment information. Moreover, the concentration of strontium after treatment decreased less than 10 times. In the treatment of spent catalyst from a second petroleum refinery based on treatment information of spent catalyst from the first petroleum refinery, the concentrations of cobalt, selenium, and strontium decreased more. This suggests that the artificial intelligence technology with machine-learning program improved its treatment plan for spent catalyst after gathering treatment information from spent catalyst treatment as opposed to IFA treatment.

Table 9: Spent catalyst treatment results

Contaminant	Before treatment (mg/L)	After treatment of spent catalyst from first petroleum refinery (mg/L)	After treatment of spent catalyst from second petroleum refinery (mg/L)	China local standard (mg/L)
Aluminum	9.3	0.17	0.14	NA
Arsenic	14	<0.004	<0.004	5
Barium	58	0.83	0.76	100
Beryllium	3	0.35	0.28	NA
Cadmium	11	<0.0001	<0.0001	NA
Cobalt	1.6	1.4	0.083	1
Chromium	47	0.0073	0.0052	5
Copper	1.7	<0.0004	<0.0004	NA
Iron	80.4	0.0018	0.0009	NA
Lead	247	<0.0005	<0.0005	5
Magnesium	4.4	0.049	0.036	NA
Manganese	1.5	<0.0001	<0.0001	NA
Mercury	0.00006	0.00005	0.00005	0.2
Molybdenum	8.3	0.102	0.074	NA
Nickel	469	<0.005	<0.005	NA
Silver	0.0038	0.0010	0.0004	5
Selenium	2	1.3	<0.002	1
Strontium	98	11	0.69	NA
Titanium	27	0.64	0.58	NA
Vanadium	104	0.66	0.61	NA
Zinc	6.8	0.94	0.85	NA

As the operator wished to use the treated spent catalyst in concrete, the re-composition unit was switched on to sort out particles that were between 3 mm and 20 mm and between 20 mm and 50 mm and each size fraction was to be incorporated into concrete formulation to substitute 1% to 2% of sand and stone, respectively.

Claims

The claims of system and method for solid waste treatment are as follows.

1. The integrated and universal intelligent solid waste treatment system comprising the following that work together in synergy:

- (a) A processor with memory that stores the treatment methods, adopts artificial intelligence technology, and executes instructions for the selection of suitable treatment strategies based on the information about solid wastes and the specific environmental and/or material utilization standards/guidelines.
- (b) Drying unit;
- (c) Sieving unit that separates solid waste particle by size;
- (d) Treatment chamber housing washing, ultrasonication and scum removal functions;
- (e) Chemical immobilization and/or decomposition unit;
- (f) Sensor network and algorithm system that continuously monitors the concentrations of pollutants including soluble salts, heavy metals and organic pollutants and automatically adjusts washing liquid, and dosages of chemical immobilization and/or decomposition agents in the treatment chamber;
- (g) Magnetic separator and eddy current separator units;
- (h) Wastewater treatment unit; and
- (i) Solid waste particle re-composition unit.

2. The intelligent and universal solid waste treatment method comprising:

- (a) A comprehensive database stored in the moment that provides treatment strategies for various environmental pollutants and harmful substances in the environmental and/or material utilization standard/guideline;
- (b) Analysis of the solid waste information using the processor to classify the solid waste materials into groups of A, B, C, and D such that:

A is incineration bottom ash with material heterogeneity and particle size distribution approximately 50 mm to below 1 mm,

B is powdery or consists of lumps of powdery material and has particle size distribution below 1 mm,

C has moisture content 40% to 70% and particle size distribution approximately 60 mm to below 1 mm,

D is harder particles having particle size distribution below 30 mm and the particle sizes are relatively uniform; and

(c) Innovative treatment methods for different solid wastes to meet a variety of environmental and/or material utilization standard/guideline developed and simulated by artificial intelligence software.

3. The method of claim 2, further comprising comprehensive testing of solid wastes to aid in development and simulation of innovative treatment methods.

4. Method of treating solid waste of groups A, B, C, and D as specified in claim 2, using the system of claim 1, and wherein the drying unit dries the solid waste material by warm air blower to a maximum moisture content of 30 to 40% for groups B and C and that is switched off for groups A and D.

5. The method of treating solid waste in claim 4 wherein the sieving unit sieves solid waste particles such that for group A fine particles are below 3 mm, medium-sized particles are 3 to 20 mm, and coarse particles are 20 to 50 mm and that for groups B, C, and D the sieving unit is bypassed.

6. The method of treating solid waste in claims 4 and 5 wherein for groups A and D inside the treatment chamber, washing liquid is water, an aqueous solution of inorganic acid, an aqueous solution of an organic acid, a complexing agent, and combinations thereof, the inorganic acid is hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid, and combinations thereof, the organic acid is citric acid, oxalic acid, or acetic acid, and combinations thereof, and complexing agent is ethylenediaminetetraacetic acid, ethylenediamine-N,N'-disuccinic acid, nitrilotriacetic acid, ethylenediamine, dimercaprol, ammonium citrate, and combinations thereof, and for groups B and C the washing function is switched off.

7. The method of treating solid waste in claims 4 to 6 wherein ultrasonication frequency inside the treatment chamber is 65 to 85 MHz for group A, 5 to 25 MHz for group D, and the ultrasonication function is switched off for groups B and C.

8. The method of treating solid waste in claims 4 to 7 wherein

For group A fine particles, 10% to 20% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition;

For group A medium-sized particles: 5% to 15% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition;

For group A coarse particles: 0.1% to 10% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition;

For group B, 5% to 50% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition;

For group C: 1% to 20% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition; and

For group D: 2% to 10% of chemical agents selected from the group consisting organic sulfurs, inorganic sulfurs, hydroxides, phosphates, carbonates, bicarbonates, oxidants, or combinations thereof are added to chemical immobilization and/or decomposition.

9. The method of treating solid waste in claims 4 to 8 wherein the sensor network and algorithm system continuously monitors the concentration of environmental pollutants and harmful substances, and automatically adjusts the volume of washing liquid until concentration of environmental pollutants and harmful substances is below value determined by the database of claim 2 (a).

10. The method of treating solid waste in claims 4 to 9 wherein the magnetic separator removes ferrous particles and the eddy current separator removes aluminum and other nonferrous particles for group A and for groups B, C, and D the magnetic separator and eddy current separator are switched off.

11. The method of treating solid waste in claims 4 to 10 wherein for groups A and D the wastewater treatment unit comprises a flocculating or coagulating step using a chemical that is selected from the group consisting of aluminum sulfate, ferric chloride, ferric sulfate, ferrous sulfate, polyacrylamide, polyaluminum chloride, polyaluminum chlorosulfate, polyaluminum silicatesulfate, sodium alginates, polyelectrolytes, and combinations thereof and for groups B and C the wastewater treatment unit is switched off.

12. The method of treating solid waste in claims 4 to 11 wherein,

For groups A and D, the solid particle re-composition unit reassembles the treated solid waste particles such that coarse particles are 2 to 20 mm and fine particles are <2 mm, and treated coarse particles of 2 to 20 mm in size substitute 5% to 50% of stones and fine particles of size <2 mm substitute 10% to 50% of sand in concrete marking formulation;

For group B, the solid particle re-composition unit is switched off;

For group C, the solid particle re-composition unit separates treated solid waste particles that are of size <2 mm to substitute 5% to 10% of sand in concrete making formulation.

13. The method of claims 2 to 12 can be further improved and optimized by the artificial machine learning techniques with the feedback of each treatment effectiveness.