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(54) **METHOD FOR REPROCESSING SOLID COMBUSTION PRODUCTS OF COAL**

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(57) **ABSTRACT**

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A method for reprocessing solid combustion products includes the combustion products first being mixed with a base before the mixture obtained is sintered, wherein the sintered mixture can be washed out with an acid solution after sintering.

## METHOD FOR REPROCESSING SOLID COMBUSTION PRODUCTS OF COAL

### BACKGROUND

[0001] The present invention relates to a method for reprocessing solid combustion products of coal, especially hard coal/bituminous coal. Combustion products within the meaning of the present invention can comprise all solid combustion residues that arise in the combustion of coal, preferably hard coal/bituminous coal, and/or that may remain after the combustion of preferably hard coal/bituminous coal. Combustion products within the meaning of the present invention therefore may only arise during and/or after an actual combustion. In particular, solid combustion products within the meaning of the present invention can be combustion products of hard coal/bituminous coal and/or solid residues of such combustion such as ash, fly ash, slag and dust.

[0002] As is known, solid combustion products contain a certain amount of various elements/compounds, in particular e.g. alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids, and/or the related compounds of these elements.

[0003] In particular, combustion products can for example have traces or respectively greater or smaller portions of copper, iron, nickel, silver, lead, zinc, tin, aluminum, calcium, sodium, silicon, titanium, gold, platinum, palladium, rhodium, iridium, indium, tungsten, rhenium, thallium, niobium, uranium and/or related compounds of these elements.

[0004] For this reason, combustion products are generally collected and disposed of or respectively deposited separately to reduce the risk of potentially releasing heavy metals or other toxic substances/compounds and counteract the contamination of the environment by means of special disposal or respectively depositing.

[0005] Methods are known from the prior art for binding or respectively entrapping combustion products and the elements/compounds contained therein to secure against elution as well as possible. The combustion products are generally introduced into a binder matrix that for example can particularly comprise silicates and/or e.g. preferably glass or cement. It is the object of the corresponding methods to reliably bind the elements/compounds in the combustion products to prevent toxic elements/compounds from escaping as much as possible. In particular, this is also to ensure that no toxic elements/compounds are released even when contacted or respectively when rinsed with a suitable solution, especially e.g. with a basic or acidic solution. The substances produced by these methods that comprise a highly inert matrix with non-eluting, entrapped/introduced toxic elements/compounds can for example be deposited and/or used as glasses and/or fillers/insulating material in particular for construction elements.

[0006] Such methods are for example described in detail in unexamined laid-open patent applications DE4435618 or DE3717085.

[0007] Since however it is very difficult to obtain a completely inert matrix in which the toxic elements/compounds can be entrapped, and since the toxic elements/compounds can migrate (within the matrix and out of the matrix) and the matrix can corrode, e.g. in particular during long storage, it is impossible to completely prevent the toxic element/compounds from escaping after all.

[0008] Consequently, methods are also known in the prior art in which combustion products are washed out with acidic solutions or also with solutions that contain a binder/chelate former to remove the heavy metals from the combustion products. The fillers that are obtained accordingly have a substantially lower concentration of toxic elements/compounds which makes them substantially less problematic to use. Unexamined laid-open patent application DE4141889 describes for example a method in which ash is washed out with a solution comprising a chelate former to remove toxic heavy metals from the ash. Furthermore, unexamined laid-open patent application DE4318535 describes a method in which acidic solutions are used to wash out toxic heavy metals from the ash. The concentration of heavy metals in the ash can thereby be significantly lowered. The treated ash can then be safely used for example as a filler.

[0009] Depending on the composition of the combustion products, it can however be very difficult to sufficiently remove the toxic elements/compounds from the combustion products only by washing out.

[0010] In fact, combustion products, depending on the compositions, and in particular e.g.

[0011] combustion products and/or ashes from the combustion of coal, preferably from the combustion of hard coal/bituminous coal, can comprise e.g. a great deal of silicon dioxide and/or glass and/or insoluble or very scarcely soluble compounds, particularly insoluble or only very scarcely soluble oxides and/or preferably insoluble or only very scarcely soluble silicates, or respectively water- and/or acid-insoluble or only scarcely water- and/or acid-soluble silicates, in particular silicates and/or insoluble or only very scarcely soluble compounds and/or silicates of alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids.

[0012] Many of the toxic elements/compounds can thereby be bound or respectively enclosed in silicon dioxide and/or glass and/or insoluble or very scarcely soluble compounds, particularly insoluble or only very scarcely soluble oxides and/or preferably insoluble or only very scarcely soluble silicates, or respectively in water- and/or acid-insoluble or only scarcely water- and/or acid-soluble silicates, in particular silicates and/or insoluble or only very scarcely soluble compounds and/or silicates of alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids. Since the toxic elements/compounds therefore in this case are largely present as inclusions or respectively are bound and/or introduced into insoluble/scarcely soluble compounds, heavy metals and other toxic elements/compounds may be only very difficultly or insufficiently be freed from heavy metals and/or other toxic elements/compounds by washing them out using acidic solutions or solutions that comprise a binder/chelate former.

### SUMMARY OF THE INVENTION

[0013] It is therefore the object of the present invention to provide a method for reprocessing combustion products that makes it possible to reprocess combustion products, preferably combustion products of coal, in particular hard coal/bituminous coal, and/or further preferably combustion products that for example comprise silicon dioxide and/or glass and/or insoluble or very scarcely soluble compounds, particularly insoluble or only very scarcely soluble oxides and/or preferably insoluble or only very scarcely soluble silicates, or respectively water- and/or acid-insoluble or only scarcely

water- and/or acid-soluble silicates, in particular silicates and/or insoluble or only very scarcely soluble compounds and/or silicates of alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids to enable the sufficient removal of metals, in particular heavy metals and/or other toxic elements/compounds from these combustion products so that the residues of the combustion products can be safely processed further. Insoluble and/or scarcely soluble and/or very scarcely soluble can preferably mean water- or respectively acid-insoluble, and/or only scarcely water- or respectively acid-soluble, and/or only very scarcely water- or respectively acid-insoluble.

**[0014]** This object is achieved by a method for reprocessing the combustion products having the features of independent claim 1. Special embodiments or developments of the method according to the invention can be found in the dependent claims as well as in the subsequent detailed description of the method according to the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

**[0015]** The method according to the invention for reprocessing combustion products comprises first mixing the combustion products with a base before the obtained mixture is sintered, wherein the sintered mixture can be washed out with an acid solution after sintering. Reprocessed and washed out residues of the combustion products as well as a preferred acid solution or respectively washing solution of heavy metals or other toxic elements/compounds and/or in addition e.g. of alkali metals, alkaline earth metals, transition metals, metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements can thereby be obtained.

**[0016]** Heavy metals and other toxic elements/compounds and in addition e.g. alkali metals, alkaline earth metals, transition metals, metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements can thereby be sufficiently removed from the combustion products to ensure safe further processing of the reprocessed residues of the combustion products.

**[0017]** All of the substances or respectively mixtures of substances and/or compounds or respectively compound mixtures that are capable of forming hydroxide ions ( $\text{OH}^-$ ) in an aqueous solution can be considered a base within the meaning of the present invention.

**[0018]** However, mineral bases and/or alkalis and/or bases that comprise an element from the family of alkali metals and/or alkaline earth metals are preferably used as a base according to the invention. In addition, mixtures of two or more of such bases may be used as a base in the method according to the invention.

**[0019]** In particular, bases that comprise potassium and/or sodium can also be preferably used according to the invention.

**[0020]** By adding a base, and in particular a base that comprises at least one alkali metal and/or alkaline earth metal, especially sodium and/or potassium, substances/elements/compounds, especially alkali metals and/or alkaline earth metals, especially sodium and/or potassium, may be added to the combustion residues so that more or respectively primarily e.g. water- and/or acid-soluble compounds, especially for example water- and/or acid-soluble aluminates and/or silicates, especially alkali silicates, preferably water- and/or acid-soluble alkali silicates, such as sodium or potassium

silicates ( $\text{NaSiO}_3$  or  $\text{KSiO}_3$ ) can be formed while subsequently sintering the mixture of the base and combustion products. In particular, according to this also insoluble or only very scarcely soluble compounds and/or oxides and/or silicates, in particular water- and/or acid-insoluble, or only scarcely water- and/or acid-soluble silicates can accordingly be converted during sintering into water- and/or acid-soluble compounds and/or oxides and/or silicates, especially into alkali silicates, preferably into water- and/or acid-soluble alkali silicates, and more preferably e.g. sodium or potassium silicates ( $\text{NaSiO}_3$  or  $\text{KSiO}_3$ ).

**[0021]** In the method according to the invention, only a single base that is in particular e.g. not a mixture of bases is preferably added to the combustion products. This can make it easier to handle and store the base. A base is preferably added to the combustion products in the method according to the invention without adding additional salts and/or oxides, and in particular without adding salt(s) and/or an oxide, or respectively a plurality of oxides, that cannot be considered a base within the meaning of the present invention. Furthermore, the method according to the invention occurs before and up to sintering, including sintering preferably without adding water and/or an acid and/or the aqueous solution of an acid to the base and/or to the combustion products and/or to the mixture of the combustion products and the base. The base is preferably not added as a basic solution, in particular an aqueous basic solution. In addition, the base is preferably added in the method according to the invention after the actual combustion so that the base is added to the combustion products. This can mean in particular that preferably no more combustion occurs after the base is added in the method according to the invention.

**[0022]** In particular, hydroxides or hydrogen sulfites of alkali metals and/or alkaline earth metals can be used as a base according to the invention in the method according to the invention. A particularly preferable possibility is to also use carbonates, especially carbonates of alkali metals and/or alkaline earth metals as the base in the method according to the invention. Carbonates can preferably be used since they make it possible to introduce alkali metals and/or alkaline earth metals if applicable with a minimum amount of residues in the combustion products since slight amounts of  $\text{CO}_2$  may easily escape during sintering.

**[0023]** For example, sodium hydroxide, potassium hydroxide, sodium hydrogen sulfite, potassium hydrogen sulfite and/or a mixture thereof can preferably be used as the base. For example, sodium carbonate, potassium carbonate and/or a mixture thereof can be particularly preferably used as the base.

**[0024]** The base can be added in a stoichiometric or hyperstoichiometric amount in relation to the quantity of silicon (Si) and/or glass and/or silicon dioxide ( $\text{SiO}_2$ ) to the combustion products and possibly mixed with the combustion products, so that a ratio, and in particular a stoichiometric ratio of the base to the silicon (Si) and/or glass and/or silicon dioxide ( $\text{SiO}_2$ ), can be achieved in the mixture of the combustion products and the base that is preferably e.g. greater than or equal to 1, more preferably between 1 and 4, more preferably between 1.05 and 3, more preferably between 1.1 and 2, more preferably between 1.15 and 1.5, more preferably between 1.2 and 1.4, wherein a ratio, in particular a stoichiometric ratio, between 1 and 1.2 and in particular 1 and 1.1 can be particularly preferable.

**[0025]** In addition, to sinter/sintering in the method according to the invention comprises at least partially melting the particles of the combustion products, especially the combustion products of coal, preferably hard coal/bituminous coal, and the particles of the base, preferably at an elevated temperature. The terms “to sinter” and “sintering” can be used synonymously.

**[0026]** It can in particular be relevant for the combustion products, especially combustion products of coal, preferably hard coal/bituminous coal and/or possibly their contents and the base, to react with each other preferably at an elevated temperature while the particles of the combustion products and particles of the base at least partially melt.

**[0027]** The temperature during sintering can preferably for example lie between 100° C. and 2000° C., preferably between 200° C. and 1700° C., more preferably between 300° C. and 1600° C., more preferably between 400° C. and 1500° C., more preferably between 450° C. and 1450° C., more preferably between 500° C. and 1400° C., more preferably between 550° C. and 1350° C., more preferably between 600° C. and 1300° C., more preferably between 625° C. and 1275° C., more preferably between 650° C. and 1250° C., more preferably between 675° C. and 1225° C., more preferably between 700° C. and 1200° C., more preferably between 712.5° C. and 1187.5° C., more preferably between 725° C. and 1175° C., more preferably between 737.5° C. and 1150° C., more preferably between 750° C. and 1125° C., more preferably between 762.5° C. and 1100° C., more preferably between 775° C. and 1087.5° C., more preferably between 787.5° C. and 1075° C., more preferably between 800° C. and 1057.5° C., more preferably between 805° C. and 1050° C., more preferably between 810° C. and 1037.5° C., more preferably between 815° C. and 1025° C., more preferably between 820° C. and 1012.5° C., more preferably between 825° C. and 1000° C., more preferably between 830° C. and 990° C., more preferably between 835° C. and 980° C., more preferably between 840° C. and 970° C., more preferably between 845° C. and 960° C., more preferably between 850° C. and 950° C., more preferably between 852.5° C. and 940° C., more preferably between 855° C. and 930° C., more preferably between 857.5° C. and 915° C., more preferably between 860° C. and 900° C., more preferably between 865° C. and 895° C., more preferably between 870° C. and 890° C.

**[0028]** Sintering can in particular e.g. take place over 0.1 hours to 4 hours, preferably 0.2 hours to 3 hours, more preferably 0.25 hours to 2 hours, and more preferably 0.5 hours to 2 hours.

**[0029]** After sintering, the sintered mixture of combustion products and the base can then be washed out with an acid solution.

**[0030]** Heavy metals and other toxic elements/compounds as well as e.g. alkali metals, alkaline earth metals, transition metals, metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements can thereby be washed out of the sintered mixture. In the method according to the invention, in particular heavy metals and preferably also precious metals and/or transition metals can be washed out and transferred to the washing solution.

**[0031]** Within the meaning of the present invention, particularly e.g. a mineral acid, especially nitric acid, hydrochloric acid or chloric acid, or respectively a corresponding solution, especially an aqueous solution of one of these acids, can preferably be used as the acid solution that is used for washing out. In addition, mixtures of two or more of these acids or

respectively corresponding solutions can be used if applicable. These acids can preferably form at least water- or acid-soluble complexes of toxic elements/compounds, especially of alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids so that these can be dissolved and converted into an aqueous phase/solution if applicable.

**[0032]** Particularly preferably, hydrochloric acid or respectively a hydrochloric acid solution can be used. This can be heated relatively easily and also recycled, if necessary, in a possibly closed circuit and reused. Preferably a solution can be used as the acid solution that only comprises a single acid so that in particular a solution is not used that comprises a mixture of two or more acids. This can simplify the handling of the acid solution if applicable as well as its reprocessing and recycling.

**[0033]** For example, a 10 to 75%, preferably 15 to 60%, more preferably 20 to 45% aqueous acid solution can be used to wash out the sintered mixture of the combustion products and base. Particularly preferable are e.g. 10 to 30% and more preferably 10 to 25% acid solutions, or respectively preferably aqueous acid solutions.

**[0034]** In particular, e.g. a 10 to 20% hydrochloric acid solution, preferably a 10 to 20% aqueous hydrochloric acid solution, can be used to wash out the sintered mixture of combustion products and the base.

**[0035]** “To wash out with an acid solution” according to the present invention can for example mean that an acid solution can be simply added to the sintered mixture of combustion products and the base, wherein the solution or respectively washing solution and washed-out residues of the sintered mixture of combustion products and the base are then and/or simultaneously separated using suitable means, in particular e.g. by filtration. Then an acid solution can e.g. be added to the sintered mixture of combustion products and the base to wash it out until toxic elements/compounds and in addition also e.g. alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semi-metals, lanthanoids and actinoids or related compounds of these elements are sufficiently removed from the sintered mixture of combustion products and the base so that the washed out residues from the sintered mixture of combustion products and the base can be easily further used after being washed out.

**[0036]** In another embodiment of the method according to the invention, an acid solution or respectively the acid contained therein can be used for washing out preferably e.g. at a stoichiometric or hyperstoichiometric amount in relation to the concentration of oxides and/or especially the oxides that form the primary components of the combustion products, and/or silicon (Si) and/or glass and/or silicon dioxide (SiO<sub>2</sub>) and/or aluminum (Al) and/or aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) and/or sodium (Na) and/or sodium oxide (Na<sub>2</sub>O) in the combustion products, and/or preferably in the sintered mixture of the combustion products and the base, or respectively added to the sintered mixture of combustion products and the base. Accordingly a ratio, especially a stoichiometric ratio of acid to oxides and/or especially to the oxides that form the primary components of the combustion products, and/or to silicon (Si) and/or to glass and/or to silicon dioxide (SiO<sub>2</sub>) and/or to aluminum (Al) and/or to aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) and/or to sodium (Na) and/or to sodium oxide (Na<sub>2</sub>O) that is preferably e.g. greater than or equal to 1, more preferably between 1 and 4, more preferably between 1.05 and 3, more preferably between 1.1 and 2, more preferably between 1.15 and 1.5;

more preferably between 1.2 and 1.4 can be achieved in the mixture of the acid solution and the sintered mixture of combustion products and the base obtained thereby, wherein a ratio, especially a stoichiometric ratio, between 1.1 and 1.35 can be especially preferable.

**[0037]** In another embodiment of the method according to the invention, the acid solution for washing out can first be preferably added at room temperature to the sintered mixture of the combustion products and the base and preferably mixed or respectively stirred before the washing solution and washed-out residues of the sintered mixture of combustion products and the base are possibly separated, for example by filtration.

**[0038]** In another embodiment of the method according to the invention, the acid solution for washing out can first be preferably added at room temperature to the sintered mixture of the combustion products and the base and preferably mixed or respectively stirred, and the mixture of the acid solution and sintered mixture of combustion products and the base may then be heated preferably before the washing solution and washed-out residues of the sintered mixture of combustion products and the base are separated, for example by filtration.

**[0039]** The heating can in particular e.g. be at a temperature between 25° C. and 300° C., preferably between 50° C. and 200° C., more preferably between 75° C. and 150° C., more preferably between 90° C. and 125° C., and particularly preferably between 25° C. and 90° C. Heating can preferably be effected and/or especially be sustained until a gel forms. The formation of a gel can make it possible to particularly effectively wash the toxic elements/compounds and in addition e.g. also the alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements out of the gel. Preferably the formation of a gel can enable heavy metals and/or in particular precious metals and/or transition metals to be effectively washed out of the gel, wherein the heavy metals and/or especially precious metals and/or transition metals can be effectively transferred into the washing solution. Heating can in particular last e.g. between 0.1 hours to 24 hours, preferably between 0.25 hours to 20 hours, more preferably between 0.3 hours to 15 hours, more preferably between 0.5 hours to 12 hours, more preferably between 0.75 hours and 10 hours, more preferably between 0.9 hours and 7.5 hours, more preferably between 1 hour and 5 hours, more preferably between 1.25 hours and 3 hours, and more preferably between 1.5 hours and 2 hours. After the gel is formed, the possibly remaining part of the washing solution can then be separated from the gel for example by filtration to finish washing out.

**[0040]** In another embodiment of the method according to the invention, the gel that may be formed during washing out by heating and can be considered a washed-out residue of the sintered mixture of the combustion products and the base can be dried after being separated (which can for example be done by filtration) from any possibly remaining part of the washing solution and hence after washing out. Drying can for example occur at a temperature between 20° C. and 500° C., more preferably between 40° C. and 400° C., more preferably between 50° C. and 300° C. more preferably between 60° C. and 250° C., more preferably between 70° C. and 200° C., more preferably between 80° C. and 150° C., more preferably between 90° C. and 125° C., especially preferably between 25° C. and 70° C., and/or in a vacuum. The drying time can in

particular be e.g. 0.25 hours to 4 hours, preferably 0.5 hours to 3 hours, and more preferably 1 hour to 2 hours.

**[0041]** In another embodiment of the method according to the invention, the gel or dried gel, assuming that the gel is dried, can be ground in one or more steps. This can be done analogous to grinding the sintered mixture of the combustion products and the base. A granulate/powder with an average particle size of 0.001 mm to 50 mm, preferably from 0.01 mm to 45 mm, more preferably from 0.1 mm to 40 mm, more preferably 0.1 mm to 35 mm, more preferably 0.1 mm to 30 mm, more preferably 0.1 mm to 1 mm can thereby be obtained.

**[0042]** In another embodiment of the method according to the invention, the gel, or the dried gel assuming that the gel is dried, that may also have been ground, can be further washed out with an acid solution in one and/or a plurality of steps before separating the washing solution and the washed out residues. The gel or the dried gel (assuming that the gel has been dried) which may also have been ground, can in particular be washed out in addition to washing out the sintered and possibly also ground mixture of combustion products and the base during which the gel may form. The method according to the invention can accordingly comprise at least two washing out steps in which acid solutions are used for washing out. In a first washing out step, the mixture of the combustion products and the base may possibly be washed out, and a gel may be formed. In a second washing out step, the gel or the dried gel (assuming that a gel was dried) that may also have been ground can be washed out. Thereby e.g. a mineral acid, especially nitric acid, hydrochloric acid or chloric acid or respectively a corresponding solution, especially an aqueous solution of one of these acids, can also be used as the acid solution for washing out the gel or the dried gel (assuming that the gel was dried) which may also have been ground. A mixture of two or more of these acids or a corresponding solution can also be used. Preferably, however, a solution can be used as the acid solution that only comprises a single acid so that in particular a solution is not used that comprises a mixture of two or more acids. This can simplify the handling of the acid solution if applicable as well as its processing and recycling.

**[0043]** Particularly preferably, hydrochloric acid or respectively an aqueous hydrochloric acid solution can be used. This can be heated relatively easily and also possibly recycled in a preferably closed circuit and reused. By correspondingly recycling and by processing the hydrochloric acid or respectively hydrochloric acid solutions, the hydrochloric acid can be reused to significantly reduce the amount of hydrochloric acid that is actually consumed by the method. In addition, the same acid or respectively a solution of the same acid can be used preferably during the entire method for washing out. Consequently, a plurality of different acids do not have to be stored, handled and disposed of or respectively reprocessed.

**[0044]** For example, a 1 to 12.5%, preferably 2 to 10%, more preferably 3 to 7.5%, more preferably 3.5 to 6%, more preferably 4 to 5%, preferably aqueous acid solution can be used to wash out the gel or the dried gel (assuming that the gel was dried) which may also have been ground.

**[0045]** In particular, e.g. an approximately 5% hydrochloric acid solution, in particular a 5% aqueous hydrochloric acid solution, can be used to wash out the gel or the dried gel (assuming that drying took place) which may also have been ground.

**[0046]** Washing out is more effective assuming that the gel or the dried gel (assuming that drying took place) was ground

before being washed out, so that toxic elements/compounds and furthermore also e.g. alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements can be very effectively removed from the gel or the dried gel if applicable.

**[0047]** In another embodiment of the method according to the invention, the gel or dried gel (assuming that drying took place) which may also have been ground can be washed out in a plurality of steps and/or with a plurality of portions of an acid solution. In particular, the gel or dried gel (assuming that drying took place) which may also have been ground, can be washed out or respectively repeatedly washed out using for example at least 2, preferably between 3 and 10, and more preferably between 4 and 6 portions of an acid solution. The washing solution and washed out residues each can be separated after each portion or after each washing out step (for example by filtration). By repeatedly washing out the gel or the dried gel that may also be ground, toxic elements/compounds and in addition e.g. also alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements may be removed particularly effectively from the gel or the dried gel.

**[0048]** During each washing out step according to the invention, the washing solution and washed out residues, respectively, are preferably separated. This separation can for example be by filtration, centrifuging and/or by the mere settling of the washed out residues. The washing solution can in particular be an aqueous solution that comprises the acid used for washing out as well as the toxic elements/compounds and/or the washed out alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements that were washed out of the mixture of the combustion products and the base and/or the gel (dried or undried, or ground or unground), and/or the already washed out residues. The washed out residues can be the preferably insoluble and/or scarcely soluble, especially water-insoluble and/or only scarcely water-soluble residues that remain after washing out, especially after washing out the sintered mixture of the combustion products and the base, and/or after washing out the gel (dried or undried or ground or unground), and/or after washing out the already washed out residues.

**[0049]** In another embodiment of the present invention, the washed out residue can optionally be dried and then annealed. The optional drying can for example occur at a temperature between 25° C. and 500° C., more preferably between 40° C. and 400° C., more preferably between 50° C. and 300° C., more preferably between 60° C. and 250° C., more preferably between 70° C. and 200° C., more preferably between 80° C. and 150° C., more preferably between 90° C. and 125° C., especially preferably between 100° C. and 110° C., and/or in a vacuum. The optional drying time can in particular be e.g. 0.25 hours to 4 hours, preferably 0.5 hours to 3 hours, and more preferably 1 hour to 2 hours. In addition, the annealing can e.g. be at a temperature between 250° C. and 3000° C., preferably between 500° C. and 2500° C., more preferably between 750° C. and 2000° C., more preferably between 900° C. and 1500° C., and more preferably between 1000° C. and 1200° C. Annealing can for example last between 0.25 hours and 10 hours, more preferably between 0.5 hours and 7.5 hours, more preferably between 0.75 hours and 5 hours, more

preferably between 1 hour and 3 hours, and more preferably between 1.5 hours and 2 hours. Silicon dioxide can be obtained from the residues.

**[0050]** The washing solution can in particular be an aqueous solution, or a 0.2 to 0.5% preferably aqueous hydrochloric acid solution comprising the acid that was used for washing out as well as the washed out toxic elements/compounds and/or the washed out alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements. The washing solution can also be reprocessed for binding, separating and/or recycling the substances dissolved therein. In particular the alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids that may be dissolved in the washing solution can for example be preferably removed separately by means of an electrolysis method and/or by precipitation, and/or supplied to further processing/recycling. In particular in the method according to the invention, e.g. heavy metals and/or precious metals and/or transition metals can preferably be removed separately by an electrolysis method and/or by precipitation, and/or supplied to further processing/recycling.

**[0051]** In another embodiment of the method according to the invention, the base and/or the combustion products can also be dried before the base is added to the combustion products. Drying can preferably occur e.g. at a temperature greater than or equal to 50° C., preferably greater than or equal to 100° C., more preferably at a temperature between 110° C. and 400° C., more preferably at a temperature between 120° C. and 300° C., more preferably at a temperature between 150° C. and 200° C. and/or in a vacuum. The drying time can in particular be e.g. 0.1 hours to 4 hours, preferably 0.25 hours to 3.5 hours, more preferably 0.5 hours to 3 hours, more preferably 1 hour to 2 hours. More preferably, the base can for example be dried in particular for 1 hour to 2 hours at 200° C.

**[0052]** In addition, the mixture of the combustion products and the base can be dried before sintering in another embodiment of the method according to the invention. Drying can preferably occur e.g. at a temperature greater than or equal to 50° C., preferably greater than or equal to 100° C., more preferably at a temperature between 110° C. and 400° C., more preferably at a temperature between 120° C. and 300° C., more preferably at a temperature between 150° C. and 200° C. and/or in a vacuum. The drying time can in particular be e.g. 0.1 hours to 4 hours, preferably 0.25 hours to 3.5 hours, more preferably 0.5 hours to 3 hours, more preferably 1 hour to 2 hours. More preferably, the mixture of the combustion products and the base can for example be dried in particular for 1 hour to 2 hours at 200° C.

**[0053]** In another embodiment of the method according to the invention, the sintered mixture of the combustion products and the base (obtained after sintering) can be ground in one and/or a plurality of steps before being washed with an acid solution. A granulate/powder with an average particle size of 0.001 mm to 50 mm, preferably from 0.01 mm to 45 mm, more preferably from 0.1 mm to 40 mm, more preferably 1 mm to 35 mm, more preferably 5 mm to 30 mm, more preferably 0.1 mm to 1 mm can thereby be obtained. Grinding the sintered mixture of the combustion products and the base enables the improvement and greater effectiveness of washing out with an acid solution since the contact between the acid solution and sintered mixture of the combustion products

and the base can be improved by grinding. After grinding the contact surface between the sintered mixture of the combustion products and the base and the acid solution is substantially greater so that the acid solution better rinses the ground sintered mixture of the combustion products and the base which is therefore more effectively washed out. This enables the possibly very effective removal of in particular toxic elements/compounds and in addition e.g. also alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements from the combustion products.

**[0054]** In another special embodiment of the method according to the invention, the grinding of the sintered mixture of the combustion products and the base can also occur in a plurality of steps. In particular, the sintered mixture of the combustion products and the base can first be only coarsely ground in an initial step to e.g. obtain a granulate/powder having an average particle size of 30 mm to 50 mm, preferably 25 mm to 40 mm, more preferably 20 mm to 30 mm, and particularly preferably 0.1 mm to 1 mm. In a second and/or plurality of additional step(s), the sintered mixture of the combustion products and the base already coarsely ground in the first step can be reground to e.g. obtain a granulate/powder having an average particle size of 0.001 mm to 10 mm, preferably 0.01 mm to 5 mm, and particularly preferably 0.1 mm to 1 mm. In particular, toxic elements/compounds and furthermore e.g. alkali metals, alkaline earth metals, transition metals, metals, heavy metals, precious metals, semimetals, lanthanoids and actinoids or related compounds of these elements can be washed out more effectively from the sintered mixture of the combustion products and the base the smaller the sintered mixture of the combustion products and the base are ground.

**1-14.** (canceled)

**15.** A method for reprocessing solid combustion products of coal, comprising the steps of mixing the combustion products with a base to form a mixture; sintering the mixture; before the obtained washing out the sintered mixture with an acid solution after sintering, wherein said base is selected for the group consisting of a mineral base, a base comprising an element from the family of alkali metals and/or alkaline earth metals, is one of potassium and sodium, hydroxides, hydrogen sulfites, carbonates of alkali metals, and alkaline earth metals, and wherein said acid solution is selected from the group consisting of a mineral acid, nitric acid, hydrochloric acid, chloric acid ( $\text{HClO}_3$ ), and an aqueous solution of one of said acids.

**16.** The method for reprocessing combustion products according to claim **15**, wherein said base is added to the combustion products in a stoichiometric or hyperstoichiometric amount in relation to a concentration of silicon (Si) and/or silicon dioxide ( $\text{SiO}_2$ ), wherein the ratio, of the base to silicon (Si) and/or silicon dioxide ( $\text{SiO}_2$ ) is greater than or equal to 1.

**17.** The method for reprocessing combustion products according to claim **15**, wherein said sintering step occurs at a temperature of  $100^\circ\text{C}$ . to  $2000^\circ\text{C}$ . over a period of 0.1 hours to 4 hours.

**18.** The method for reprocessing combustion products according to claim **15**, further comprising adding the acid solution for washing out is to the sintered mixture of the combustion products and the base, and wherein the washing

solution and washed-out residues of the sintered mixture of the combustion products and the base are then or simultaneously separated by filtration.

**19.** The method for reprocessing combustion products according to claim **15**, wherein the acid for washing out is added to the combustion products at a stoichiometric or hyperstoichiometric amount in relation to a concentration of oxides and/or oxides that form primary components of the combustion products, and/or silicon (Si) and/or silicon dioxide ( $\text{SiO}_2$ ) and/or aluminum (Al) and/or aluminum oxide ( $\text{Al}_2\text{O}_3$ ) and/or sodium (Na) and/or sodium oxide ( $\text{Na}_2\text{O}$ ), wherein a ratio, of acid to oxides and/or the oxides that represent the primary components of the combustion products, and/or to silicon (Si) and/or to silicon dioxide ( $\text{SiO}_2$ ) and/or to aluminum (Al) and/or to aluminum oxide ( $\text{Al}_2\text{O}_3$ ) and/or to sodium (Na) and/or sodium oxide ( $\text{Na}_2\text{O}$ ) is greater than or equal to 1.

**20.** The method for reprocessing combustion products according to claim **15**, further comprising adding the acid solution for washing out at room temperature to the sintered mixture of the combustion products and the base, and heating the mixture of the acid solution and sintered mixture of the combustion products and the base at a temperature between  $25^\circ\text{C}$ . and  $300^\circ\text{C}$ . before the washing solution and washed out residues of the sintered mixture of the combustion products and the base are separated by filtration.

**21.** The method for reprocessing combustion products to claim **20**, further comprising forming a gel.

**22.** The method for reprocessing combustion products according to claim **21**, further comprising the gel during washing out and considering a washed-out residue of the sintered mixture of the combustion products, and drying the base at a temperature between  $20^\circ\text{C}$ . and  $500^\circ\text{C}$ . after being separated from any possible remaining part of the washing solution.

**23.** The method for reprocessing combustion products according to claim **21**, further comprising crushing or grinding the gel in one or a plurality of steps.

**24.** The method for reprocessing combustion products according to claim **23**, further comprising washing out the crusted or ground gel with an acid solution in one and/or a plurality of steps, and separating the washing solution and the washed out residues of the gel.

**25.** The method for reprocessing combustion products according to claim **15**, further comprising drying the washed out residues and annealing said residues at a temperature between  $250^\circ\text{C}$ . and  $3000^\circ\text{C}$ .

**26.** The method for reprocessing combustion products according to claim **15**, further comprising drying the base and/or the combustion products at a temperature greater than or equal to  $50^\circ\text{C}$ . for a period of between 0.1 hours and 4 hours before the base and the combustion products are mixed.

**27.** The method for reprocessing combustion products according to claim **15**, further comprising drying the mixture of the combustion products and the base at a temperature greater than or equal to  $50^\circ\text{C}$ . for a period of between 0.1 hours and 4 hours before sintering.

**28.** The method for reprocessing combustion products according to claim **15**, further comprising grinding the sintered mixture of the combustion products and the base that is obtained after sintering in at least one step before being washed out with an acid solution.