Climate Cooling by Interaction of Natural (a) or Artificial (b) Loess Dust with Tropospheric Methane

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Abstract

First, this publication deals with the ferric salt photolysis functioning as modelling constituent of loess dust (LD) particle surfaces which takes place in the time of LD residence in the troposphere. Second, the causal interdependence between the LD's observed and indicated additional oxidative properties and ancient climate changes is discussed. Last, feasibility and probable consequences of the planned geo-engineering project are considered, the aim of which is the reversion of climate warming by means of artificial LD emission.

Introduction

Growing attention is paid to the influences of LD to the climate. Reacting with acidic and acid-creating tropospheric constituents to salts, LD reacts as well to ferric salts. Own observations support the theory of ferric chloride decomposition under exposure to sunlight (37). To harden this finding and to examine the behaviour of other ferric salt constituents, further observations have been conducted, the results of which are displayed hereunder.

Experimental

- Impregnation of round filters of cellulose fiber paper and glas fiber paper with water-soluble chloride-, bromide-, fluoride-, nitrate- and sulfate-ferric salts.

- Exposure of both, wet and dry impregnated round filters to sunlight without any shielding, to sunlight shielded by window glass and to darkness for a period of three hours each.

- In order to prove the emission of chlorine and bromine from the exposed ferric salt impregnation, phenole-charged passive samplers were placed at small distance from the exposed surfaces of the round filters (step 1). After the exposure period the passive samplers were extracted by an organic solvent. The extract was analyzed by GC-MS to identify halogene phenoles as a proof of chloro- resp. -bromo-emission from the exposed ferric halogenide (step 2).

- In order to prove the developement of NOx from the ferric nitrate impregnation, pyrene-charged passive samplers were placed as described (step 1). Then followed extraction of passive samplers and identification of nitro pyrenes in the extract by GC-MS (step 2). The detection of nitro pyrenes was taken as a proof of NO_x emission from the exposed ferric nitrate. All step 2 analysis were performed by K. Steinbach, University of Marburg, Dep. of Chemistry, Div. Mass Spectrometry.

- To prove the developement of ferro salts, the exposed round filters were hydrolyzed by dipping them into diluted caustic soda solution. The resulting grey, grey-green or black coloration was taken as detection sign of ferro salts, while an ochre coloration identifies their absence. As ferro hydroxides re-oxidate rapidly into ochre ferri hydroxides, the hydrolysis proof had to be conducted immediately upon hydrolysis.

Results (table 8)

The sunshine-exposed ferric chloro-, bromo- and nitrate-salts emitted chlorine resp. bromine resp. NOx. Iron salt impregnated cellulose fiber and Iron salt impregnated glas fiber from direct and glas-shielded sunlight exposure showed different reactions depending of the carrier substance: Ferric fluoro- and sulfate-salts did not decompose on glas fiber paper, but they decomposed on cellulose fiber paper. No ferric salt decomposition at all took place under exposure to darkness. The assumed chemical reactions are collected under 3) to 7) and 12) to 17) in List 1.

Consequence of the findings relating to LD climate interaction (table 9)

While the above results represent but a sector of natural LD chemistry, another sector is governed by the strong hydroxyl radical oxidation power of the ferro salt-hydrogen peroxide reaction system simplified by formula 11), known under the term „Fenton-reaction" (FR). FR is in use as water cleaning process (tables 1 and 2). The oxidation power of the simple FR is increased by photolysis. This variation is called „photo Fenton reaction" (photo-FR). Titanium dioxide photolysis, described in formula 10), is part of the reaction medium of several of the photo FR-variants. Additional other semiconductor oxides as well may be involved in the photo reaction. Thus the reactions of LD under sunshine exposure are photo-FR. LD-FR are to define as photo FR during day time and FR during night time. Photo FR runs not short in reactants: Ferro salts and peroxides are photolytic by-products. Hydroquinones, additional constituents of LD, are capable of reducing oxygen into peroxide in the darkness as described by formula 8). Concerning the latter, FR may take place continuously on LD in a sustained mode without consumption of any FR educts, as the composition's of LD provides all necessary substances (table 3). Additional, sunshine radiation will keep LD in its powerful oxidant mode (table 4).

Today's atmospheric chlorine freight is comparatively low due to chlorine reduction by CH_4 into hydrogen chloride and rapid wash out of the water soluble hydrogen chloride (table 5, picture 1), while the CH_4 freight in the atmosphere is rising. For some part this might owe to the decrease of the atmospheric hydroxyl radical concentration, the latter caused by consumption through reducing source gases and organic particulate matter increasingly emitted from agriculture, urban areas, wildfires and partly by the CH_4 emissions of temperature rise dependant destabilization of CH_4 hydrate sediments (table 6).

It is commonly known that the LD maxima in the last glacial period coincide with the minima of CH_4, CO_2 and climate temperature (table 7). Considering the known facts and the results given in table 8, the picture of LD action within the troposphere becomes more transparent: Increasing LD freights in the troposphere induce substancial changes of the tropospheric hydroxyl- and chlorine-radical cycles by catalyzing an additional oxidative re-transformation of hydrogen chloride to chlorine and by inducing an elevated hydroxyl radical level. This will result in a substancial decline of chloride rain out and may even raise the tropospheric chlorine fright may be, up to domination of the methane chlorine radical oxidation rate over the methane hydroxyl radical oxidation rate (picture 2).

Following this causal chain, an increase of LD will substancially reduce the atmosphere's CH_4 freight. Along with further LD-dependent effects such as the growth rate of methane hydrate- and kerogen-sediment mass by the plancton fertilizing effect of iron (picture 3), the increase of sulfur- and halogen-methanes emission during plancton bloomings by the same causality and albedo increase are expected to jointly lower the tropospheric temperature level (table 9). Most probably the increase of the tropospheric chlorine- and hydroxyl-radical freight promises to trigger additional cooling effects through enhancing the decomposition of gases of low reactivity such as carbon monoxide, carbonylsulfide and dinitrogen oxide. Another indication for the influence of LD on climate is the fact, that glacials coincide with the build-up of super continents, occuring about every 400 million years (T. Hubble et al. [41]). This is supported by the assumption, that the percentage of desert area covering a super continent is significant exceeding that of a world splitting into several continents. The LD burden of the troposphere in the super continental phase should be at a substancially higher level than found in the maxima of the recent glacial. Provided, the oceanic currents during such super continent period will not cross polar regions (A.G. Smith et al. [42]), the elevated LD levels would certainly trigger an ice age.

Consequence of the results relating to the feasibility of artificial climate cooling

To stop and reverse the trend of global warming, the described effects of LD offer an optimum geo-engineering tool if aptly employed in a concerted, world-wide project, according to the recently published proposal (table 10). The emission of artificial LD by simple incineration of iron- and titanium dominated metal organyl mixtures provides the advantage in sparing costly development and construction of specific technical installations, as the combustion of oils charged by iron- and manganese-organyl additives in oil burners and internal combustion machines has been well proven and is in common practice since long. Processing the incineration of metal organyl additive charged fuels in aircraft turbojet machines is the most simple procedure: the organyl charged fuel combustion shall be restricted to the afterburner fuel, preventing any turbine rotor coating by metal oxides. As those parts of the atmosphere covering the oceans represents the range where

artificial LD may unfold the maximum of ist climate cooling effects; consequently organyl-charged fuels shall be restricted for preferential supply of trans-continental vessels and aircraft engines, to distribute the artificial LD from their extended exhaust gas tracks (picture 3).

The multiple properties of artificial LD may easily be tailored to serve specific purposes: Oxidation power, refraction, colour and reflection for the artificial LD may be controlled by purpose oriented composition of the individual organyl additive. Thus, apt conditioning of artificial LD enables it to exceed the climate cooling efficiency of its natural counterpart by at least three or four orders of magnitude (table 11). If taken into the calculation to determine the physical prerequisites needed to reverse the trend of global warming, this permits substancial minimization of the artificial LD mass to be released.

As the first step to prepare the „ *Cooling Climate by Artificial Loess Dust Distribution Project (COALDIP)"* to be put into practice, different research institutions and supporting organizations have to be selected which cover all those science fields relevant to LD (table 12). Moreover, close connections, knowledge exchange, and cooperation with neighbouring LD research projects like the MAGIC- and SAMUM-project shall take place.

Further Enclosure
Tables 1 - 12, reference liest.

Table 1 The Fenton reaction (FR) is known as powerful tool in oxidative desintegration of organic substances inclusive those hard to degrade by other known means

Substance degraded by Fenton reaction	Literature Author	FR type		Citation No. within reference list
		inclusive photolysis*)	dark reaction	
Salicic acid	Qing Dai et al.	UV light		5
Polymer	Teixeira, A.C.S.C.	UV light		8
Pentachlorophenole	Fukushima, M. et al	UV light		7
Phenyl urea herbicides	Katsumata, F. et al.	UV light		13
Diisopropylphosphonate	Qasim, M. et al	UV light		14
Mineral oil Hydrocabons	Gao, Y.X. et al.		X	15
Phenole	Zheng, Z-w.	UV light		4
Aniline	Fukushima, M. et al	UV light		9
Humic Acids	White, E.M. et al.	UV light		11
Nitroaromatics	Renwranz, A.	UV light		6
Tetrachloroethene	Büyüksönmez, F. et al.		X	12
Pyrene	Sanley, C.A.		X	28
Quinoline	Valentine, R.		X	29

*) The degradation power of photo FR is more powerful than the dark FR

Table 2 The Fenton reaction (FR) may be operated with a wide variety of iron reactants

Substances bound to iron	Literature Author	FR type		Citation No. within reference list
		inclusive photolysis*)	dark reaction	
Citrate	Battacharyya, D. et al		X	24
Polyacrylate	YongChao Li et al.		X	25
Cyclodextrine complex	Wei, B.		X	27
Salicylate	Feng Chen et al.	UV light		3
Chloride	Lipchynska-Kochany, E.	UV light		1
Chloride	Domenech et al. X.	UV light		35
Ionic exchange polymer	Wanhong Ma et al.	UV light		2
Hydroquinone complex	Feng Chen et al.	vis. light		3
Fe-Cu-Mn-Y-Zeolithe	Zheng, Z-w.	UV light		4
Iron-silicon mix oxid	Yue, P.L.	UV light		23
Ferrihydrite	Barreiro, J.C. et al.		X	26
EDTA complex	Qing Dai et al.	UV light		5
NTA complex	Abida, O. et al.	UV light		22
Sulfate	Renwranz, A.	UV light		6
Sulfate	Domenech et al. X.	UV light		35
Humic acid complex	Fukushima, M. et al	UV light		7

*) The degradation power of photo FR is more powerful than the dark FR

Table 3 Tropospheric aerosols contain numerous ingredients suitable to operate FR

Selected Substances	Publication Author	Citation No. with feren
Inorganics		
Water	Jacob, D.J.	36
Hydrogen peroxide	K. Bächmann et al.	30
Sulfate	Jacob, D.J.	36
	K. Bächmann et al.	30
Sulfuric acid	Jacob, D.J.	36
Nitrate	Jacob, D.J.	36
	K. Bächmann et al.	30
Nitrite	K. Bächmann et al.	30
Chloride	Jacob, D.J.	36
	K. Bächmann et al.	30
Ammonium	Jacob, D.J.	36
	K. Bächmann et al.	30
Hydrogenperoxide	Jacob, D.J.	36
Persulfate	Jacob, D.J.	36
silicates	Jacob, D.J.	36
metal oxides	Jacob, D.J.	36
Calcium carbonate	Jacob, D.J.	36
Iron(II)- and Iron(III)-Compounds	Jacob, D.J.	36
	K. Bächmann et al.	30
Manganese(II)- and Manganese(III)-Compounds	Jacob, D.J.	36
Copper(I)- and Copper(II)-Compounds	Jacob, D.J.	36
Titanium compounds	Johannsen et al.	39
Organics		
aliphatic Hydrocarbons		
C10 - C30-aliphatic Hydrocarbons	Finlayson-Pitts, B.J., Pitts, J.N.	31
aromatic Hydrocarbons		
2-ring - 5-ring-aromatic Hydrocarbons	Finlayson-Pitts, B.J., Pitts, J.N.	31
Coumarine	Finlayson-Pitts, B.J., Pitts, J.N.	31
peri-Naphthenone	Finlayson-Pitts, B.J., Pitts, J.N.	31
Xanthone	Finlayson-Pitts, B.J., Pitts, J.N.	31
Anthrone	Finlayson-Pitts, B.J., Pitts, J.N.	31
Flavone	Finlayson-Pitts, B.J., Pitts, J.N.	31
Benzoanthrone	Finlayson-Pitts, B.J., Pitts, J.N.	31
Carbazole	Finlayson-Pitts, B.J., Pitts, J.N.	31
Quinoline	Finlayson-Pitts, B.J., Pitts, J.N.	31
Methylindoles	Finlayson-Pitts, B.J., Pitts, J.N.	31
Dimethylindoles	Finlayson-Pitts, B.J., Pitts, J.N.	31
Dimethylquinolines	Finlayson-Pitts, B.J., Pitts, J.N.	31
Nitrophenolic compounds	Winterhalter, R. et al.	19
Quinone- / Hydroquinone Systems		
Dihydroxybiphenyls	Skarek, M. et al.	17
Diphenoquinones	Skarek, M. et al.	17
Dihydroxybenzenes	Olariu, R.-I. et al.	18
Nitrocatechole	Winterhalter, R. et al.	19
1,2,10-trihydroxy-anthracene	Rudich, Y.	21
Humic substances	Rudich, Y.	21
black carbon soot	Jacob, D.J.	36
Carboxylic acids		
Oxalic acid and other dicarboxylic acids	Finlayson-Pitts, B.J., Pitts, J.N.	31
	K. Bächmann et al.	30
Biogenic dicarboxylic acids	Winterhalter, R. et al.	19
Tricarboxylic acids	Winterhalter, R. et al.	19
C9 - C21 linear fatty acids	Finlayson-Pitts, B.J., Pitts, J.N.	31
Oleic acid	Finlayson-Pitts, B.J., Pitts, J.N.	31
Linolic acid	Finlayson-Pitts, B.J., Pitts, J.N.	31
Linolenic acid	Finlayson-Pitts, B.J., Pitts, J.N.	31

Table 4 **Known facts support the thesis that Fenton reaction (FR) is of sustained activity in iron containing LD, transforming LD into a powerful oxidant**

- The iron(II)-hydrogenperoxide reaction system is known as FR (reaction 6).
- FR effective destroys organic matter by hydroxyl radical oxidant attack (table 1).
- The photo-FR in general has more oxidative power in organic matter degradation than FR in the dark (tables 1 and 2).
- Many kind of oxidic, organic and inorganic compounds bound to iron(II) have been tested suitable as effective educts in the FR (table 2).
- Photolysis transforms organic iron(III) compounds into Fenton educt Iron(II) (John Herschel 1862).
- Iron compounds inclusive organics and inorganics suitable for effective FR are constituents of LD (table 3).
- Sunshine-disposed titanium oxidic compounds combined with hydroquinones: This system combination is suitable of sustained generation of the FR reagent hydrogenperoxide during day and night. Both reactants are known as constituents of LD (table 3).
- The occurence of photo-FR has been postulated (D.J. Jacob [36]). Educts and Products of FR have been found on iron containing tropospheric aerosols (W. Jäschke, K. Bächmann et al. (30), A.M.Johannsen [39]).
- Sunshine photodecomposition of nitrates are known to yield OH-radicals and NOx. Ferro- and ferric-nitrates shall act by the same way (W.-U. Palm, W. Behnke, C. Zetzsch [54])

Table 5 **Today's atmospheric chlorine freight is very low depending on the chlorine reduction by methane oxidation to hydrogen chloride and wash out of the latter**

- Atmospheric chlorine is transformed by reaction with methane to hydrogen chloride; hydrogen chloride is washed out by condensed water (J.H. Seinfeld [33], B.J. Finlayson-Pitts, J.N. Pitts [53]).
- Aliphatic hydrocarbons react much faster with chlorine radicals than with hydroxyl radicals (C. Zetzsch [16b])
- Chlorine Atoms (= Chlorine radicals) are more reactive than Hydroxylradicals (M.B. da Rosa, C. Zetzsch [16a]).
- The reaction rate constant for the chlorine-methane reaction is almost two orders of magnitude greater than that for the hydroxyl radical-methane reaction (P.L. Tanaka, D.T. Allen [50]).
- Stratospheric maximum daytime concentration relation of the molecules: chlorine radikal to hydroxyl radical to hydrogen chloride is today at the level of around 1 to 150 to 1000 (P. Fabian [52]). The equivalent relation of these molecules within the troposphere is believed not to differ by more than one order of magnitude.
- The emission freights of a) organic halogene from the oceans have been calculated to 5 to 10 metric megatons of organic bound halogens per year (D.B. Harper, [57a]) per year and b) that of originally sea salt bound halogene to about 10 gigatons per year (W.C. Keene, [57b]).

Table 6 **The atmospheric methane freight increase may be due to the hydroxyl radical decrease (Finlayson-Pitts, J.N. Pitts [53]). Part of the klimate warming effects may be the OH-radical decrease-induced methane increase**

- In the current atmosphere hydroxylradicals are believed to be the main oxidant for methane decomposition (B.J. Finlayson-Pitts, J.N. Pitts [53])
- Currently global methane concentration is increasing and global hydroxylradical concentration is decreasing [I.S.A. Isaksen (51)]. One of the reasons thereof may be the increasing emissions of reducing gases from urban areas and 'wildfires.
- Next to water vapour and CO2, methane is the third main greenhouse gas, taking part in the current climate warming trend. Though little discussed by Kyoto, present day actual warming from methane is about 50 % of that from CO2. One gram of methane has the same warming power than sixty gram of CO2 (E.G. Nisbet (45]).
- Instabilities of methane hydrat sediments might induce sudden Methane emission events (E.G. Nisbeth [45], G. Ryskin [46]).

Table 7 **LD maxima correlate with methane-, CO2- and climate temperature-minima.**

- Precipitation of the iron containing LD induce plancton blooms transforming atmospheric CO2-carbon into methane hydrate sediment carbon within the oceanic sediment (J.K.B. Bishop et al. [40]).
- Results of fertilization tests of the oceanic plancton by iron sulfate solution have led to recommendations to cool the climate and increase the fish population by iron salt solutions (K.O. Buesseler [47]).
- LD particle maxima of drill cores of glacier ice back to 750 000 years have shown close correlation to glacial maxima (J.R. Petit et al. [34])
- Minima of the atmospheric greenhouse gas content of both of the gases CO2 and methane, are closely correlated to glacial maxima, maxima of greenhouse gases content are bound to the warm inter glacials (P.J. Samson [10]).
- Indirect evidence of climate cooling by LD maxima is given by the fact, that cold climate periods resp. glacials coincide with supercontinent formation (T. Hubble et al. [41]). Supercontinents are characterized by huge desertified areas with larger LD mass production than that of small continents separated by oceanic basins.

Table 8   Own observation results

**Sunshine photo decomposition of ferric chloride results in chlorine emission -
this seems to be one of the most important result of the observation**

- Inorganic ferric salts containing chloride, bromide, nitrate, sulfate and fluoride are photo-decomposed by sunshine into iron(II) compounds and oxidants. Photo decomposition oxidants identified as derivatives are chlorine, bromine and NOx; photo decomposition reductants identified as hydroxide coloration is iron (II) [Reaction formulas 3 to 5 and reaction formulas 12 to 17].
- Cellulose fiber paper or on glass fiber paper got a coat by ferric salt-water solution as wet coating or as dried coating
- The photo decomposition products chlorine and bromine have been detected by capturing the halogene radicals from the gaseous phas with phenole as mono- and dihalogene phenole derivatives adsorbed on a passive sampler.
- The photo decomposition product NOx has been detected by capturing the NOx radicals from the gaseous phase with pyrene as mono and dinitropyrene derivatives adsorbed on a passive sampler.
- The iron(II) photo decposition product has been prooven immediate after hydrolyzation as greygreen to greyblack fast reoxidizing coloration of the iron salt in direct contact to sunshine or below window glass to sunshine.
- No substanciel difference has been found, when the photo decomposition reaction was carried out with dry ferric salt or ferric salt in solution.
- cellulose filter paper resulted in a more intense photo decomposition reaction to iron(II) compounds than glass fiber paper.
- Parallel tests under the same reaction conditions in the darkness did not give any reaction.

Table 9   New facts as cosequences of the own observation results in the LD reaction

**Considering the facts in tables 1 to 7 the observation results in table 8 leads to the postulation:
LD induce substancial changes in the tropospheric chlorine cycle by catalyzing the hydrogen chloride re-transformation to chlorine. This will result in substancial depression of chloride rain out. This may increase the tropospheric chlorine freight to the level the chlorine radical oxidation rate of methane dominates over the hydroxyl radical oxidation rate of methane. Hydroxyl radical production by photo FR on the LD additional may increase the Hydroxyl radical level.
By this causal chains rising LD levels will induce substanciel level reductions of the atmospheric freights of methane and other reducing gases.**

- Iron containing aerosols, represented by LD, catalyze the re-transformation of the tropospheric hydrogen chloride freight back into the halogen radical freight. This transformation even may work during night time.
- At high LD content levels within the troposphere the chloride to chlorine transformation will significant increase the chlorine radical concentration in the troposphere, because the halogen freight is prevented from loss by chloride precipitation.
- Increasing troposphering chlorine conc. will raise the ferric chloride proportion of the LD particle composition.
- The hydroxyl radical dominated methane oxidation regime of the prior LD-poor atmosphere will change into an chlorine radical dominated methane oxidation regime after LD-enrichment of the troposphere.
- Additional enrichment of halogene radical freight is expected by increased emissions of halogene methanes by the parallel iron-induced plancton bloomings below the LD enriched troposphere.
- Thus the changed chlorine cycle by an LD-rich troposphere might significant reduce the methane content of the atmosphere.
- Chlorine radicals as well have affinities to substances with double or triple bondings. This is well known from the photolytic carbon monoxide chlorine reaction to phosgene (J. Davy, 1812) or from ozone decomposition by chlorine. This reaction might get evidence, because the atmospheric CO burden will go on rising (J. Lelieveld [56]). Possibly chlorine reactions with carbonyl sulfide or dinitrogen oxide have to be considered too in a chlorine enriched troposphere.
- Because LD equivalent surfaces is found here to be a source of different radicalic oxidants halogene atoms, hydroxyl and NOx, LD is expected to be an heterogenic tropospheric liquid-solid catalyst system with extended reactivities to aliphatic, unsaturated and aromatic tropospheric organics and mineralization capacity even to substances with high oxidation resistance (Tab. 1 und 2).
- Additional oxidative mineralization of all non-methane organic freight of the troposphere, especially the increased dimethylsulfide emissions of the plancton bloom below the LD-enriched troposphere is expected.
- According to its outstanding oxidative power LD should gain the title "tropospheric cleaning agent".
- Because of its oxidation power LD aerosol is coatet very fast by sulfate as oxidation product from organic sulfur.
- The acidic hygroscopic sulfate covered surface of the iron rich LD will cover faster and at lower relative humidities than iron-poor non-LD with liquid solution and by this serve as cloud condensing particles, acting as albedo intensifying agent.

Table 10	Technical production and destinating the emission lines of artificial LD

**Most active artificial LDwithin the troposphere may be produced at low cost
and without any additional technical equipment from iron organyle additive to ship and
aircraft fuel [F.D. Oeste, E. Ries (43)]**

- Oil containing iron- and titanium-organyles used as fuel additives to ship- and aicraft engines will produce exhaust gases containing oxidic iron- and titanium-aerosols. This artificial aerosol is designated by this as "artificial LD".
- Typical low price iron- and titanium organyl fuel additives are represented by naphthenates, ferrocenes and titanocenes.
- Artificial LD emitted from the widespread use of iron organyles as heating oil additives to increase efficiency and to reduce the soot content of the fluegas has not posed any problems to health and environment within the urban areas of Europe and North America.
- The chemical property of the artificial LD to self-develop hygroscopic liquid layers around the particles induces immediate condensation and agglomeration resulting in conversion of the primary micro particles to coarser grained aerosol which in no way may pose health and environment problems.

Table 11	Target properties of organyl descendent artificial LD as climate controll tool

**The possibility to reverse the climate warming trend simply by the means of
exhaust gas emission of artificial LD along the ship- and aircraft tracks is
a fascinating imagination. The many indicatons given in the tables give support that
this imagination may be feasible.**

- Due to high iron content, primary particle size and specific surface area artificial LD is expected to gain a specific methane reduction capacity of about 3 to 4 orders of magnitude over that of natural LD.
- The sunlight-reflecting properties and photocatalytic properties of the artificial LD are pre-diterminable by variation of the iron- and titanium-content and possible further constituents of the artificial LD. This allows to design an artificial LD with an optimal combination of maximum sunlight reflectance, maximum oxidation power and maximum hydrogen chloride to chlorine conversion power.
- Additional the pre-determinable element composition of the artificial LD will allow the determination of parameters like alkalinity / acidity, halogen radical generation activity / hydroxyl radical generation activity, peroxide generation activity. This will allow, to design the artificial LD as an tool of high variability and sensitivity to keep the atmosphere just in the optimum composition in the sense of climate stabilization, radiative properties, ozone layer constance, contents of OH-radicals, greenhouse gases, urban and natural contaminations.
- Parallel or independent of climate regulation the outstanding oxidation power of artificial LD shall be used to mineralize any organic urban emission freight as well as wildfire emissions and volcanic emissions.
- The geo-engineering project of oceanic plancton fertilization by iron salts proposed as climate cooling tool might not work because the plancton blooms would induce massive emission increase of organics, halogene methanes and sulfur methanes (M.G. Lawrence [55]). Other disadvantages to the environment may be not excluded (S.W. Chisholm et al. [48]). The organic emissions into the atmosphere might further drop down the atmospheric hydroxyl radical content, followed by methane rise according to the hydroxyl radical decrease. This effect might be compensated by parallel emission of artificial LD. Hence both geo-engineering processes might successful cooperate.

Table 12	Step examples to realize the project climate cooling by artificial LD

**All project steps ought to be realized under supported international research carried
out by cooperating research institutions covering all relevant science fields.
Close connection and cooperation to neighbouring research projects like the
MAGIC- and SAMUM-Projects**) shall be realized.**

- Bench scale testing: Chemical, physicyl, biological and health properties of the artificial LD.
- Smog chamber testing: Influence of artificial LD on the reactions of methane, hydrogen chloride and other relevant gases under day- and night conditions. LD particle size developement during different conditions.
- Ship track testing: LD particle testing at short residence time.
- Aircraft track testing: LD particle testing at maximum residence time.

**)   MAGIC = Mineral Aerosols and Glacial-Interglacial Cycles: This is a Swedish-German-French cooperation, partially funded by the Swedish NFR. The goal is to understand the role of LD in climate changes (Anonymus [44]).
SAMUM = Saharan Mineral Dust Experiment: In this DFG-Projekt, different German groups cooperate. The influence of the Saharan LD on the global climate shall be investigated (J. Heintzenberg et al. [38]).

References

Citation No.	Year of Publication	Authors	Publication
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