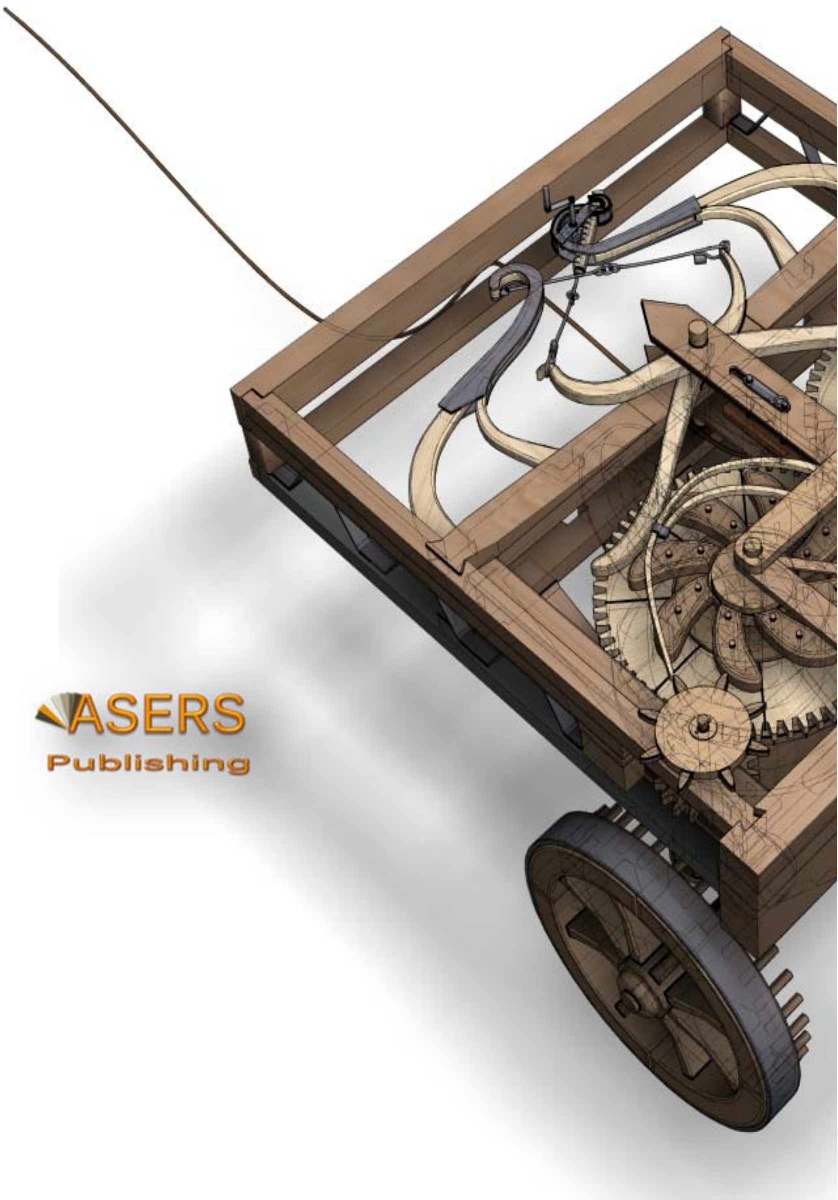
ASERS

Journal of Environmental Management and Tourism



Quarterly
Volume XI
Issue 3(43)
Summer 2020
ISSN 2068 – 7729
Journal DOI
https://doi.org/10.14505/jemt

ASERS Publishing

Summer 2020
Volume XI
Issue 3(43)

ASERS Publishing
http://www.asers.eu/asers-publishing
ISSN 2068 – 7729
Journal DOI: https://doi.org/10.14505/jemt

Table of Contents:

Summer 2020
Volume XI
Issue 3(43)

ASERS Publishing
http://www.asers.eu/asers-publishing
ISSN 2068 – 7729
Journal DOI: https://doi.org/10.14505/jemt

Call for Papers
Fall Issues 2020
Journal of Environmental Management and Tourism

Journal of Environmental Management and Tourism is an interdisciplinary research journal, aimed to publish articles and original research papers that should contribute to the development of both experimental and theoretical nature in the field of Environmental Management and Tourism Sciences.

Journal will publish original research and seeks to cover a wide range of topics regarding environmental management and engineering, environmental management and health, environmental chemistry, environmental protection technologies (water, air, soil), pollution reduction at source and waste minimization, energy and environment, modeling, simulation and optimization for environmental protection; environmental biotechnology, environmental education and sustainable development, environmental strategies and policies, etc. This topic may include the fields indicated above, but are not limited to these.

Authors are encouraged to submit high quality, original works that discuss the latest developments in environmental management research and application with the certain scope to share experiences and research findings and to stimulate more ideas and useful insights regarding current best-practices and future directions in environmental management.

Journal of Environmental Management and Tourism is indexed in SCOPUS, RePEC, CEEOL, ProQuest, EBSCO and Cabell Directory databases.

All the papers will be first considered by the Editors for general relevance, originality and significance. If accepted for review, papers will then be subject to double blind peer review.

Deadline for submission:	31st August 2020
Expected publication date:	September 2020
Website:	https://journals.aserspublishing.eu/jemt
E-mail:	jemt@aserspublishing.eu

To prepare your paper for submission, please see full author guidelines in the following file: JEMT_Full_Paper_Template.docx, then send it via email at jemt@aserspublishing.eu.

DOI: https://doi.org/10.14505/jemt.v11.3(43).26

Effect of Swine Bone Powder for Reduce Cadmium Uptake by Rice

Sasithorn PECHRSAN
Chulalongkorn University, Thailand
sasithornpechrsan@gmail.com

Thares SRISATIT
Navamindradhiraj University, Thailand
srisatit.thares@gmail.com

Suggested Citation:

Pechrsan, S., Srisatit, T. (2020). Effect of Swine Bone Powder for Reduce Cadmium Uptake by Rice. *Journal of Environmental Management and Tourism*, (Volume XI, Summer), 3(43): 721 – 727. DOI:10.14505/jemt.v11.3(43).26

Article's History:

Received 29th of March 2020; Received in revised form 30th of April 2020; Accepted 18th of May 2020; Published 22nd of June 2020.

Abstract:

The effect of swine bone powder application on bioavailability of Cd in contaminated soil from Tak Province, Thailand were conducted. The bioavailability of Cd was investigated in term of the uptake by rice plant (Oryza sativa L.) in green house at three different application rates of swine bone powder amended soil, including 5, 10 and 15%, respectively. The result demonstrated that the efficiency of cadmium uptake in Khao Dawk Mali 105 rice were in range 0.18-0.20 % and the 5% swine bone amended soil had a positive effect on promoting plant growth and seed yield. Cd concentration in both of shoot and roots decreased with increasing the swine bone application rates. Cadmium bioaccumulation in plant root to soil and translocation factor from root to shoot was less than one. The results indicated that swine bone powder-amended soil could be an alternative and cost-effective method to support plant growth and decrease Cd mobility in soil.

Keywords: swine bone; Cadmium Uptake; *Oryza sativa* L.; pollution control.

Jel Classification: Q15; Q24; Q52.

Introduction

On 1950, soil contamination by cadmium have been occurred at Shinju watershed in Japan. The main way of cadmium receiving from rice consumption that is production from agriculture area of Shinju watershed (Thongdeelert, 2012). These similar situation occured in Mae Sod, Tak Province, Thailand. Cadmium contamination is discovered in soil and rice by International Water Management Institute (IWMI). The first phase of the study (from 1998-2000) was done in most potentially area where water was naturally supplied by Mae Tao Creek in which sediment suspected of having high contamination of cadmium. Cadmium level in 154 soil samples ranged from 3.4-284 mg Cd/kg soil which was 1.13-94 times European Community (EC) Maximum Permissible (MP) soil cadmium concentration of 3.0 mg Cd/kg soil and 1,800 times the Thai standard of 37 mg Cd/kg soil. Moreover, rice samples from 90 fields were found to be contaminated with cadmium ranging from 0.1-4.4 mg/kg rice while the mean background Thai rice cadmium concentrations was 0.043±0.019 mg/kg rice (Pollution Control Department. 2004).

The second phase of the study, from 2001-2003, was expanded to cover the downstream part of Mae Tao Creek. Cadmium level in soil samples higher than 1,450 times cadmium mean level in soil of Thailand. Rice samples were contaminated with cadmium at the level higher than Committee on Food Additives and Contaminants (CCFAC). This concentration of cadmium could lead to 38.5 times higher than Committee on Food Additives and Contaminants (CCFAC) (Department of Primary Industries and mines. Cadmium contamination in Environment

Amphur Maesot, Tak Province). The result of cadmium concentration from first phase as same as cadmium concentration in Japan that lead to Itai-Itai desease.

There are many methods can be applied for the restoration of highly metal-contaminated sites (Zwoniter, Pierzynski and Hettiarachchi 2003) such as clear-cut solution and soil cleaning by means of chemical, physio-chemical or biological techniques, However, the cost such management is rather and difficult for general practice. The in-situ immobilization of the metals using sequesting agents such as apatite, zeolite or activated carbon approach is an attractive alternative to many current remediation methods. Immobilization of metals reduces both leaching and plant bioavailability

Bone is a mixed compound adsorbent in which carbon is distributed throughout a porous structure of hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$ or CaHAP). CaHAP is a major component of teeth bones and phosphate rock. It contains around 76% (Cheung *et al.* 2001). It has been reported the physical and chemical properties of the CaHAP that; the removal mechanism has been suggested to be not only an adsorption effect but also a type of ion-exchange reaction between the ions in solution and the calcium ions of the apatites (Danny *et al.* 2004). In this form, the major compound, CaHAP, in bone has been developed as a treatment for decontaminating polluted water (Gabadon *et al.* 1996; Dabbi, Azzi and Guardia 1999; Wilson *et al.* 2001). Previous studies have showed that bone char amendments could effectively immobilize Pb, Cd, Cu, and Zn in contaminated soil (Chen *et al.* 2006; Lin, Zhang and Su 2007) and significantly decrease the concentration of Pb in rice root (Huang *et al.* 2006).

Poorly crystalline apatite, such as bone apatite has been recommended to a low-cost, readily available phosphate source that could be used to remediate metal-contaminated soils without causing excessive P runoff (Ma, Logan and Traina 1995; Ma and Rao 1997). In addition, bone apatite can decrease mobility of herbicides and as the fertilizer simultaneously (Kassio Ferreira Mendes *et al*. 2019) and could be used to restore the productivity of P-depleted and degraded soils which is urgently required for increase world food production (Nadia Glæsner *et al.* 2019).

This study aimed to use the swine bone reduce cadmium uptake by rice (*Oryza sativa* L. var Khao Dawk Mali 105) and conduct to examine the effects of swine bone addition on cadmium uptake in contaminated soil.

1. Methodology

1.1. Experimental Soil and Amendments

The contaminated Soil (0-30 cm in depth) was collected from an agricultural area at Pha Tae village, Mae Sot district, Tak province, Thailand. The sampling site location was N 16.668332, E 98.606766. Soil was thoroughly mixed to homogeneous, air-dried and ground to pass through a 2 mm sieve.

1.2. Soil Characteristics

Prior to use for pot experiment the soil will be characterized to obtain the physical and chemical properties, including soil texture, soil pH, cation exchange capacity (CEC), % organic matter (OM), % total nitrogen (N), C/N ratio, available phosphorus (P), extractable potassium (K), and extractable magnesium (Mg) were analyzed.

Table 1. Some basic properties of the soil studied

Parameters	Results
pH (1:2 W/V)	8.11
Soil Texture ; Sand : Silt : Clay (%)	35 : 45 : 18
CEC (meq/100g)	15.83
Total N (%)	0.25
OM (%)	4.25
Available N (mg kg^{-1})	0.25
Available P (mg kg^{-1})	27
Available K (mg kg^{-1})	153
Available Cd (mg kg^{-1})	9.50
Total Cd (mg kg^{-1})	41.40

Moreover, to determine the total concentrations of Cd and Zn by digestion technique according to standard US EPA method 3050B (United State Environmental Protection Egency. 1996). The digested solution was analyzed with Atomic Absorption Spectrophotometer. Concentration of Cd and Zn bioavailable form was extracted by DTPA and analyzed with AAS (Quevauviller *et al.* 1998). Some basic physio-chemical properties of the soil and the concentrations of a range of elements in this soil and amendments used are listed in Table 1. Concentrations of

Cd the soil greatly exceeded those of the soil environmental quality standards in Thailand, so the soil was regarded as heavily metal-contaminated.

1.3. Swine Bone Powder

The swine bone used in this study was prepared from raw swine bones (Picnic shoulder) were cleaned and removed, soaked in brine, rinsed with tap water and boiled at 80°C for 6 hours then rinsed and gotten rid of smell with saline solution, aired dry for 2 weeks and baked in oven at 60°C for 24 hrs, crushed and milled in to small fragment. Swine bone was powdered and sieved to a 100-mesh size (150 μm) and kept it in desiccator to prepare for determines the properties of swine bone powder. The selected physico-chemical properties of bone powder used in this experiment are: surface area of 3.49 m^2 g^{-1}, CEC of 56.82 cmol kg^{-1}, 36.7 % calcium, 26.6% phosphorus, 1.01% sodium, and 0.87 % magnesium. Cadmium was not detected in bone powder.

1.4. Adsorption Isotherm of Bone Powder

Adsorption Capacity of adsorbents was analyzed by Langmuir isotherm (Okeola and Odebunmi 2001) and Cd adsorption capacity of bone powder in aqueous solution (Kołodynska *et al.* 2012; Tangjuank, Insuk, Tontrakoon and Udeye 2009; Trakal *et al.* 2011). The equilibrium batch static method was used to study the removal efficiency of bone powder by removing Cd ion from cadmium nitrate ($Cd(NO_3)_2$ solution. An initial concentration of 10 mg/L $Cd(NO_3)_2$ solution was used as Cd ion source. For each batch experimental run, 0.10 g of swine bone was weighed in each 250 mL erlenmeyer flask, 100 mL of $Cd(NO_3)_2$ was transferred to each flask. An initial pH of $Cd(NO_3)_2$ solution was adjusted to pH 6 with 0.1 M of HCl or 0.1 M of NaOH. Then, all flasks were shaken with shaker at a constant shaking speed of 175 rpm at 60 min. At the end of desired time, the remaining solution were filed through filter paper No.42 then, acidified by conc. HNO_3 to pH less than 2 and amount of cadmium (II) ion in solution were analyzed using Atomic Adsorption Spectrophotometer. The amount of Cd (II) ion adsorbed by swine bone was calculated indirectly from the remaining Cd (II) ion concentration in solution.

1.5. Treatments

A pot experiment was investigated in greenhouse. The seed of rice (*Oryza sativa* L. var Khao Dawk Mali 105) was purchase from Roi Et Rice Seed Center, Thailand. Some rice seed was analyzed cadmium and zinc accumulations before starting the experiment and another seed was cultivated in the soil for 2 weeks, but only uniform seedlings with similar weight and size will be allowed to grow in each pot. The swine bone was ground and sieved to a particle size less than 2 mm which confirms to the present soil particle size. The contaminated soil was mixed with swine bone powder at three rates: 5, 10, and 15% (w/w). The control treatment without swine bone powder was also performed. The greenhouse study was performed in triplicate, using a completely randomized design. Swine bone-amended soils were filled into (12 inch in top diameter, 18 cm in bottom diameter, and 23.5 cm in height). Each pot was filled with bone powder-amended soil to 90% pot capacity and placed in green house for 120 days with watering at field capacity before planting. Two seedlings were planted in the soil at 1 cm depth. During the process, NPK fertilizer was added to the soil after 20 days transplanting week 4 and during panicle initiation stage (Office of the Royal Development Projects Boards. 2012).

1.6. Plant and Soil Analysis

Plant samples in each treatment were collected at week 6 (Tillering stage), week 10 (the flowering stage), and week 14 (harvest stage). The harvested plants were thoroughly washed with tap water before rinsing with deionized water. For plant growth determination, root length and stem height were measured. Each plant was separated into shoot (leaf and stem) and root for weighting. Plants were oven-dried to measure dry weight. Plant were acid-digested method according to the method of US EPA method 3050B (United State Environmental Protection Egency. 1996). Cadmium and zinc concentrations in plants were analyzed by AAS. At harvesting day, the weight of rice grain will record to determine crop yield. Soil samples was collected according plant harvesting. The soil pH and concentration of acid-digested (total metal) and bioavailable forms of Cd and Zn was analyzed. In addition, the soil's chemical properties after harvest, including CEC, %OM, %N, available P, extractable K, extractable Mg, and C/N ratio, were also analyzed.

1.7. Statistical Analysis

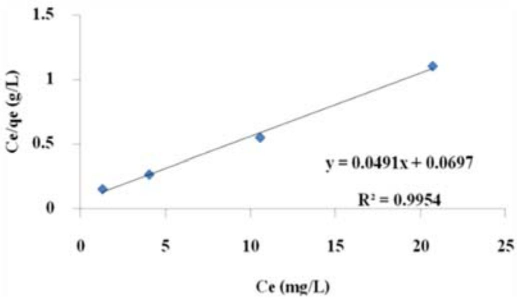
Data of all treatments were analyzed using one-way analysis of variance at 95% confidence interval. Differences among treatments will be compared by Duncan multiple range test (DMRT). All of statistical significance will set at the level of $p<0.05$. The data present are means ± S.D. (standard deviation).

2. Result and Discussion

2.1. Adsorption Efficiency of Cd ion onto Bone Powder

The Cd (II) ion adsorption characteristic on the bone powder surface fits well with the Langmuir isotherm. The maximum adsorption capacity of bone powder was 22.12 mg/g. Figure 1 shows the linear adsorption isotherm of Cd (II) ion on bone powder.

Figure 1. Langmuir isotherm of bone powder



2.2. Effect of Addition on the Growth and Uptake of Cd

Dry weight of all treatments decreased with increasing rate of bone powder application (Table 2) especially, in the 15% swine bone amended soil the growth of rice tends to be decreased when compared with other treatments due to imbalance of nutrients in soil. Some nutrient was adsorbed by high rate of bone powder application. Conversely, appropriate bone powder application help to reduce soil density, increase soil porous and benefit to growth rate of plant (Park *et al.* 2011).

Table 2. Biomass production (g/pot) of rice (*Oryza sativa* L.)

Treatments	Period Time		
	Week 6	Week 10	Week 14
0%	7.28±0.41^{c}	14.58±0.75^{bc}	34.72±2.40^{c}
5%	8.39±0.39^{d}	16.54±1.17^{c}	35.72±0.86^{c}
10%	5.89±0.27^{b}	13.17±0.44^{b}	30.36±-0.61^{a}
15%	2.64±0.36^{a}	8.78±0.40^{a}	24.15±0.83^{a}

The means and the S.E. (n=3) followed by difference lowercase letters within a column are significantly different ($p<0.05$) according to Duncan's multiple range test

Table 3. Productivity (g) of rice (*Oryza sativa* L.)

Treatments	Productivity (g)
0%	13.18±0.97^{bc}
5%	14.19±0.25^{c}
10%	12.30±0.26^{a}
15%	9.67±0.31^{a}

The means and the S.E. (n=3) followed by difference lowercase letters within a column are significantly different ($p<0.05$) according to Duncan's multiple range test

Cd concentration in plant parts during a growing period are shown in Table 4. Increasing the application of bone powder reduced the concentrations of Cd in plant parts. Cd concentrations in plant parts trended to decrease by increasing the swine bone application. The highest Cd concentration in plant shoots and roots found at the unamended treatment (0%) were 14.68, and 44.46 mg kg^{-1}, respectively and it were reduced substantially to 1.48 and 7.27 mg kg^{-1} in 15% treatment. At the flowering stage (Week 10), Cd concentrations in roots were nearly two times higher than that of week 6 due to high uptake of nutrients. At week 14, the seeding stage, the plants showed maximum uptake of nutrients for developing seeds. The bone powder addition increased Cd uptake by increasing plant growth with bone addition in soil. There was no significant difference between all treatments with bone powder amended soil. Cd concentrations in seed and husk of all treatments ranged between 0.13–1.37 mg kg^{-1} and 0.30-2.73 mg kg^{-1}, respectively, which are much higher than the Codex standard of polished rice (0.2 mg kg^{-1}). Cd concentration in seed and husk showed significant decreases with concentration of swine bone powder.

Plant uptake Cd depended on soil properties, plant species, cultivation practice, fertilizer and property of metals source (Cheney 2010). The bone meal amendments to immobilize Pb, Zn and Cd in soil, the results indicated that bone application increased high surface area of soil affect to adsorption capacity, solubility ion exchange of metals in soil (Sneddon, Garelick and Valsami-Jones 2005). The major components in bone powder are hydroxyapatite and $CaCO_3$, hydroxyapatite is not just a source for adsorption but also enables ion-exchange to occur (Ma, Logan and Traina 1995).

Table 4. Cd concentration (mg kg^{-1}) of rice (*Oryza sativa* L.) grown in Cd contaminated soil in pot culture with various bone powder amendments

Plant parts	Treatment (%)	Cd Concentration (mg kg^{-1})		
		Week 6	Week 10	Week 14
Shoot	0	13.65^{b}±0.79	13.75^{b}±0.41	14.68^{b}±3.56
	5	1.97^{a}±0.06	2.00^{a}±0.74	1.87^{a}±0.20
	10	1.50^{a}±0.10	1.67^{a}±0.21	1.57^{a}±0.12
	15	1.30^{a}±0.20	1.47^{a}±0.18	1.48^{a}±0.10
Root	0	22.86^{c}±1.66	32.40^{b}±2.69	38.50^{b}±0.82
	5	9.40^{a}±1.85	10.60^{a}±0.36	12.50^{a}±2.80
	10	8.47^{a}±1.68	8.60^{a}±2.76	8.87^{a}±0.86
	15	4.47^{a}±0.86	6.93^{a}±2.76	7.27^{a}±0.35
Grain	0			1.37^{b}±0.08
	5			0.20^{a}±0.03
	10			0.17^{a}±0.05
	15			0.13^{a}±0.04
Husk	0			2.73^{c}±0.25
	5			0.83^{c}±0.06
	10			0.60^{b}±0.10
	15			0.30^{a}±0.10

The means and the S.E. (n=3) followed by difference lowercase letters within a column are significantly different ($p<0.05$) according to Duncan's multiple range test

2.3. Efficiency of Swine Bone Powder in Reducing Cd Bioavailability in Soil

The results of the bioavailability of Cd extracted by DTPA are presented in Table 5 the results revealed that swine bone powder application could reduced Cd bioavailability in soil. Cd bioavailability decreased with increase of swine bone powder. Cd bioavailability in soil at all swine bone powder rates was not significantly difference except that in treatment of 15% was difference from other treatment. The bioavailability of Cd is in the range of 7.40-8.65 mg kg^{-1}. The highest bioavailability of Cd content was found in the treatment of 15%. These result suggest that swine bone powder amendment is effective to reduce Cd available in plant because the addition of bone powder to metals-contaminated soil resulted in a reduction in exchangeable amounts of metals in the soil and increase in the pH of the soil pore water and the soils (Chen, Zhu, Ma and Mckay 2006).

Table 5. Concentration of Cd bioavailable form in soil during planting

Treatment (%)	Cd concentration (mg kg^{-1})		
	Week 6	Week 10	Week 14
0	7.76±0.25^{a}	7.65±0.70^{a}	7.40±0.28^{a}
5	8.64±0.56^{ab}	8.35±0.60^{ab}	7.97±2.28^{ab}
10	8.48±1.57^{ab}	8.63±0.30^{b}	8.06±1.29^{ab}
15	8.65±1.00^{b}	8.18±0.52^{b}	8.17±0.82^{b}

The means and the S.E. (n=3) followed by difference lowercase letters within a column are significantly different ($p<0.05$) according to Duncan's multiple range test

Conclusion

The application of swine bone powder to Cd-contaminated soil affect to a reduction in exchangeable amount of Cd in soil and increase in the pH of soil pore water and soils. The optimum rate of swine bone powder application in soil to promote plant growth and rice yield was 5% treatment. Cd accumulated in *Oryza sativa* L. root was higher than shoot.

Acknowledgements

This research supported by grants awarded through CU Graduated School Thesis Scholarship. Graduated School, Chulalongkorn University. The authors would like to gratefully acknowledge Professor Dr.Thares Srisatit for his critical reading of the manuscript.

References

[1] Chen, S.B., Zhu, Y., Ma, Y. and Mckay, G. 2006. Effect of bone char application on Pb bioavailability in a Pb-contaminated soil. *Environmental Pollution,* 139: 433-439.

[2] Cheney, R.L. 2010. Cadmium and Zinc. In P. Hooda (Ed.), *Trace Elements in Soils*. UK: Blackwell publishing Ltd.

[3] Cheung, C.W., Chan, C.K., Porter, J.F. and Mckay, G. 2001. Film-Pore Diffusion Control for the Batch Sorption of Cadmium Ions from Effluent onto bone char. *Journal of Colloid and Interface Science,* 243: 328-336.

[4] Dabbi, S., Azzi, M. and Guardia, M. 1999. Removal of hexavalent chromium from wastewaters by bone charcoal. *Fresenius' Journal of Analytical Chemistry*, 363: 404-407.

[5] Danny, C.K.K., *et al.* 2004. Sorption equilibria of metal ions on bone char. *Gemosphere,* 54: 273-281.

[6] Gabadon, C., Marzal, P., Ferrer, J. and Seco, A. 1996. Single and competitive adsorption of Cd and Zn onto a granular activated carbon. *Water Research*, 30: 3050-3060.

[7] Huang, Y.Z. *et al.* 2006. Effects of bone char on uptake and accumulation of heavy metals by three rice genotypes (*Oryza sativa* L.). *Journal of Agro-Environmental Science*, 25 (6): 1481–1486.

[8] Kassio Ferreira Mendes *et al*. 2019. Cow bone char as a sorbent to increase sorption and decrease mobility of hexazinone, metribuzin, and quinclorac in soil. *Geoderma,* 343: 40-49.

[9] Kołodynska D., *et al.* 2012. Kinetic and adsorptive characterization of biochar in metal ions removal. *Chemical Engineering Journal,* 197: 295-305.

[10] Lin, A.J., Zhang, X.H., and Su., Y.H. 2007. Chemical fixation of metals in soil using bone char and assessment of soil genotoxicity. *Environmental Science,* 28: 232-237.

[11] Ma, L.Q. and Rao, G.N., 1997. Effects of phosphate rock on sequentialchemical extraction of lead in contaminated soils. *Journal of Environmental Quality,* 26: 788-794.

[12] Ma, L.Q., Logan, T.J. and Traina, S.J. 1995. Lead immobilization fromaqueous solutions and contaminated soils using phosphate rocks. *Environmental Science and Technology,* 29: 1118-1126.

[13] Nadia Glæsner *et al.* 2019. Crystalline apatite in bone char produced at low temperature ameliorates phosphorus-deficient soils. *Chemosphere,* 223: 723-730.

[14] Okeola, F. O. and Odebunmi, E.O. 2001. Comparison of freundlich and Langmuir isotherm for adsorption of methylene blue by agrowaste derived activated carbon. *Advances in Environmental Biology*, 4(3): 329-335.

[15] Park, J. H., *et al.* 2011. Biochar reduces the bioavailability and phytotoxicity of heavy metals. *Plant and Soil*, 438: 439-451.

[16] Quevauviller, P., *et al.* 1998. Certified reference material for the quality of EDTA and DTPA-extractable trace metal contents in calcareous soil (CRM 600). *Fresenius' Journal of Analytical Chemistry*, 360: 505-511.

[17] Sneddon, I.R., Garelick, H. and Valsami-Jones, E. 2005. *An investigation into arsenic (V) removal from aqueous solutions by hydroxylapatite and bonechar*. Mineralogical Magazine, 69: 769-780.

[18] Tangjuank S., Insuk N., Tontrakoon J. and Udeye V. 2009. Adsorption of lead (II) and cadmium (II) ions from aqueous solutions by adsorption on activated carbon prepared from cashew nutshell. World Academy of science, *Engineering and Technology*, 52: 110-16.

[19] Thongdeelert, T. 2012. "Itai-Itai desease in contamination area of Japan." Available at: http://wqm.pcd.go.th/km/images/stories/agriculture/2555/itaiitai.pdf (in Thai)

[20] Trakal, L. *et al.* 2011. Biochar application to metal-contaminated sol: evaluating of Cd, Cu, Pb and Zn sorption behavior using single and multi-element sorption experiment." *Plant, soil and Environment*, 57: 372-380.

[21] Wilson, J.A., Demis, J., Pulford, L.D. and Thomas, S. 2001. Sorption of cr (III) and Cr (VI) by natural (bone) charcoal. *Environmental Geochemistry and Health,* 23: 291-295.

[22] Zwoniter, J.C., Pierzynski, G.P. and Hettiarachchi, G.M., 2003. Effects of phosphorus additions on lead, cadmium and zinc bioavailability in a metal-contaminated soil. *Water, Air, and soil Pollution*, 143: 193-209.

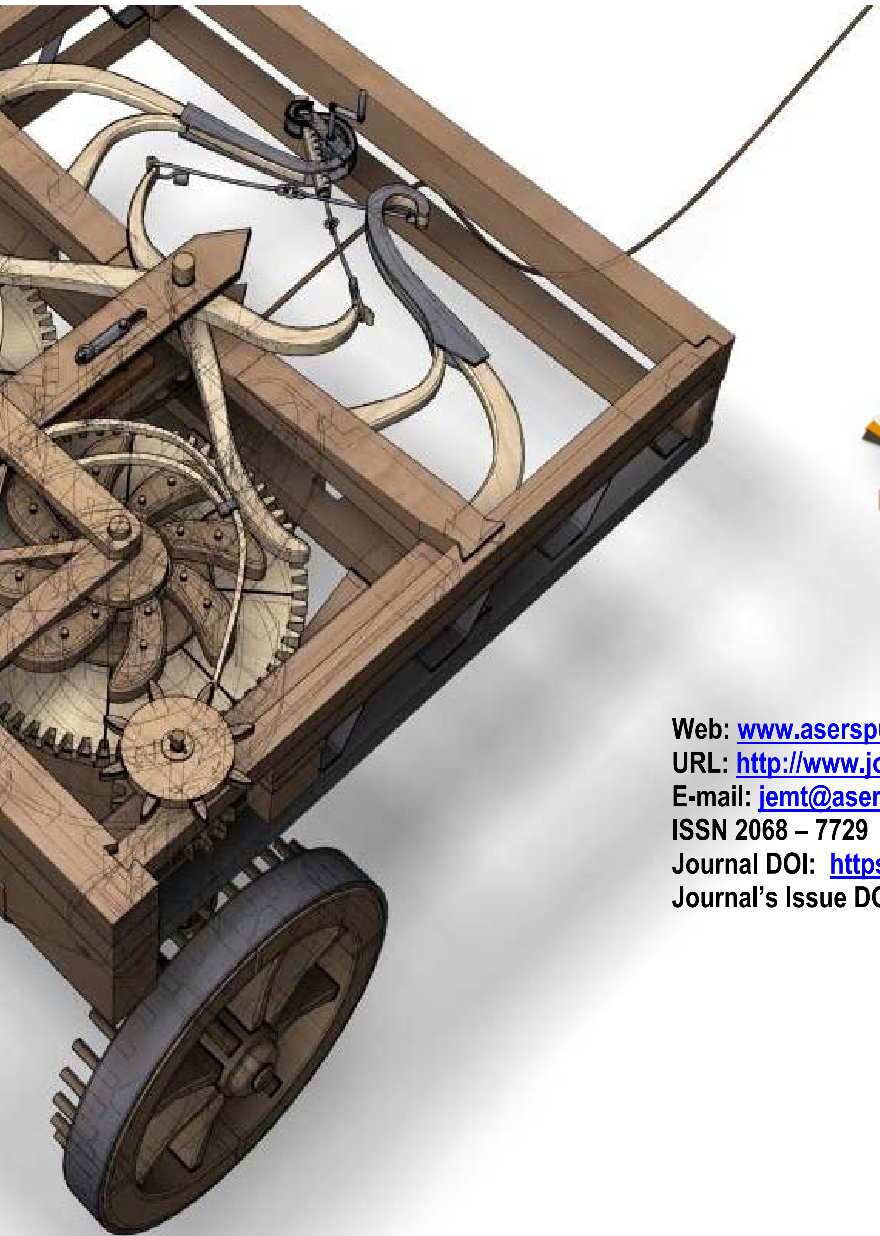
[23] Department of Primary Industries and mines. Cadmium contamination in Environment Amphur Maesot, Tak Province. Available at: http://www.dpim.go.th/laws/article?catid=122&articleid=309

[24] Office of the Royal Development Projects Boards. 2012. *The planting of Oryza sativa L. var Khao Dawk Mali 105*. Movement Gen Tree Publishing.

[25] Pollution Control Department. 2004. Summary of Environmental Samplings in Mae Sot after cadmium contamination. Bangkok: Ministry of Natural Resources and Environment, Thailand. (in Thai)

[26] United State Environmental Protection Egency. 1996. Method 3050B acid Digestion of Sediments, Sludges, and Soils: Revision 2. Available at: http://www/epa/gov/osw/harzard/testmethods/sw846/pdfs/3050.pdf

ASERS



ASERS Publishing

Web: www.aserspublishing.eu
URL: http://www.journals.aserspublishing.eu/jemt
E-mail: jemt@aserspublishing.eu
ISSN 2068 – 7729
Journal DOI: https://doi.org/10.14505/jemt
Journal's Issue DOI: https://doi.org/10.14505/jemt.v11.3(43).00