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LEAD CONTENT IN SOIL SAMPLES IN FOUR DIFFERENT SITES OF KABWE, CENTRAL PROVINCE OF ZAMBIA

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Abstract:
Pollution has increased soil lead levels to several thousand parts per million; the primary cause of soil lead contamination in Kabwe district is the weathering from the former Zinc-lead mine. Soil lead is a health risk when directly ingested or inhaled as and it is of particular concern for children less than 6 years because of its implication on their growth. Hence this study set out to assess the lead soil content in four different sites of Kabwe district, Central province of Zambia. Literature was reviewed from studies that covered soil lead contamination. A quantitative analytical study was carried out, and it involved geographical mapping of four different sites the north, South, East, and West of Kabwe district which were conveniently selected to collect soil Samples which were taken to The University of Zambia School of Mines, Geology Engineering Laboratory to determine the Levels of soil Lead content using a technique called Geo-Chemical Analysis. The results suggest that the Chowa area is highly polluted with lead metal according to the globally recommended WHO guidelines and Zambia Environmental Management Agency, which all states that Residential areas should not exceed 400Kg/mg or parts per million.

Keywords:
Soil leas; kabwe, lead exposure, lead health risk

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INTRODUCTION

Lead poisoning is one of the oldest occupational and environmental health hazards in the world. Despite its recognized hazards, lead continues to have widespread commercial applications, including the production of storage batteries, metal alloys, solder, glass, plastics, and ceramics. Environmental lead exposure, by virtue of the anthropogenic distribution of lead to air, water, and food, has declined considerably in the past three decades as a result of diminished use of lead in gasoline and other applications. Lead serves no useful purpose in the human body (Katzung, 2006).

Lead occurs naturally in the earth's crust, but much of its presence in the environment stems from its historical use in paint and gasoline and ongoing or historic mining and commercial operations (Wallace, 2008). Lead is a very soft, dense, and ductile metal. It is very stable and resistant to corrosion, although acidic water may leach out of lead pipes, fittings, and solder. It does not conduct electricity and is an effective shield against radiation (Katzung, 2006). Because of these properties, it is relatively easy to mine and work with lead. It has been used for many purposes for thousands of years. Ancient Romans used lead for plumbing, among other uses. In modern times, lead was added to paint and gasoline to improve their performance but was eliminated in the 1970s due to health concerns (Flegal, 1998).

Lead exists in two forms, which are the inorganic (found in old paint, soils, and leaded gasoline exhaust which contributed to ambient inorganic lead contamination) and the organic form (found in unburned leaded gasoline and industrial due to occupational context). Organic lead **can be more toxic** than inorganic lead because the **body more readily absorbs** it. Any potential exposures to organic lead should be taken very seriously (Katzung, 2006 & Wallace, 2008).

Accumulation of lead is the result of anthropogenic use, which has concentrated lead throughout the environment. Because lead is spread so widely throughout the environment, it can be found in everyone's body today. The levels found today in most people are orders of magnitude higher than that of ancient times

(Flegal, 1998). Toxicity is the degree to which a substance (a toxin or poison) can harm humans or animals. Acute toxicity involves harmful effects in an organism through a single or short-term exposure. Sub-chronic toxicity is the ability of a toxic substance to cause effects for more than one year but less than the lifetime of the exposed organism. Chronic toxicity causes harmful effects over an extended period, usually upon repeated or continuous exposure, sometimes lasting for the entire life of the exposed organism (Fauci, 2008).

On average, children's blood lead levels (200g/dl and above and averaging 50 and 100g/dl) in Kabwe are 5 to 10 times the permissible Environmental Protection Agency (EPA) maximum and in many cases are close to those regarded as potentially fatal. The primary source of lead toxicity in Kabwe district is as a result of contamination from decades of unsafe lead and cadmium mining and smelting (Needleman, 1990). Lead blood concentrations in Kabwe have been found at levels 60% higher than the amount considered fatal, a result of contamination from decades of unsafe lead and cadmium mining and smelting. Virtually all of this activity was unregulated through the 20th Century, allowing 100 years' worth of toxic metal to leach into the soil. Children who play in the soil and young men who scavenge the mines for scraps of metal are most susceptible to lead produced by the mine and smelter (Needleman, 1990).

Health Effects of Lead Exposure. The effects of lead in children have demonstrated a relationship between exposure to lead and a variety of adverse health effects. These effects include impaired mental and physical development, decreased haem biosynthesis, elevated hearing threshold, and decreased serum levels of vitamin D. The neurotoxicity of lead is of particular concern because evidence from prospective longitudinal studies has shown that neurobehavioral effects, such as impaired academic performance and deficits in motor skills, may persist even after Blood Lead (PbB) levels have returned to normal[6]. Although no threshold level for these effects has been established, the available evidence suggests that lead toxicity may occur at Pb levels of 10-15 mcg/dl or possibly less (ATSDR, 1990).

Children are more sensitive than adults are too elevated Blood lead levels (BLLs). Children's **developing brains** and **nervous system**s (and other organ systems) are susceptible to lead. **Childhood lead exposure** has been associated with: higher absenteeism in high school, lower class rank, more inadequate vocabulary, and grammatical reasoning scores, longer reaction time, poorer hand-eye coordination (AAP, 1993; Mathee, Naicker, & Barnes, 2009).

The incomplete development of the blood-brain barrier in fetuses and very young children (up to 36 months of age) increases the risk of lead entry into the developing nervous system, which can result in prolonged or permanent neurobehavioral disorders. Children's renal, endocrine, and hematological systems may also be adversely affected by lead exposure. There is **no known threshold exposure level** (as indicated by BLLs) for many of these effects. No blood lead threshold for adverse health effects has been identified in children (Budd, 1998).

Adults can also be exposed **to specific hobbies** and **activities** where lead is used. Some of the more common examples include Artistic painting, Car repair, Electronics" soldering, Glass or metal soldering, during which workers may inhale lead dust and lead oxide fumes, as well as eat, drink, and smoke in or near contaminated areas, thereby increasing their probability of lead ingestion. Other than the developmental effects unique to young children, health effects experienced by adults from adult exposures are similar to those experienced by children, although the thresholds are generally higher (AAP, 1993).

Lead is one of the significant heavy metal toxicity affecting the environment and human beings residing near the former lead-zinc mine in Kabwe District Central Province of Zambia. The neurotoxicity of lead is of particular concern because evidence from prospective longitudinal studies have shown that neurobehavioral effects such as impaired academic performance and deficits in motor skills, may persist even after Blood lead levels have returned to normal (Von et al., 2003). Although no threshold level for these effects has been established, the available evidence suggests that lead toxicity may occur at levels of 10-15 mcg/dl or possibly less (Gulson et al., 1994). Disposal sites account for most of the soil contamination in Kabwe. The disposal drainage line for the mine refuses used to be the primary source of Lead contamination for the surrounding community. However, the current source of soil lead contamination is from dust dispersal from the lead trailing piles, which have not been appropriately managed (Gulson et al., 1994).

For this reason, there was a need to conduct scientific research to assess the distribution patterns of Lead soil content in Kabwe district.

METHOD

The first component of the data collection process reviewed existing literature on lead soil contamination done in Zambia. The desktop research helped the study to map out key identifiable variables for understanding soil contamination as a result of lead. It also enriched the study in terms of providing policy-relevant information and help shape the design of primary data collection by producing relevant variables and research questions needed in the determination of lead contaminations in Kabwe. Data for desktop research was obtained from both published and unpublished sources. Secondly, after understanding the contexts, a quantitative Analytical Study was done.

Sources of Materials. Geographical mapping of four sites was conveniently selected were soil samples were collected and taken to the University of Zambia School of Engineering, Geology Engineering Laboratory was the Levels of soil Lead contents were determined Using a Method called Atomic Absorption Spectrometry. The study analysis unit involved the North, South, East, and West sites of Kabwe District using the distance of 20 kilometers away from the main town center distance geographical Mapping. The data collection process was conducted within one month (March 2016). This study also reviewed the literature for studies done in Kabwe since 2014. The studies that were reviewed were those that covered soil contents for Kabwe. The review was done in order to strengthen the data collections of the study.

Soil Sample Digestion. Analyzed lead in soil Sample using Atomic Absorption Spectrometry (AAS). Procedure

- Weighed about 1gram of Sample using a weighing boat in Triplicates
- Transferred quantitatively into 250ml beakers
- Added 30ml acid mixture (Aqua Regia: 3:1 HCL: HNO3) to 250mls beaker
- Heated on a hot plate for about 15 to 20 minutes, evaporated to dryness.
- Filtered into 100mls Volumetric Flasks and made up to Volume.
- Prepared working standards, being mindful of the matrix.
- Calibrated the ASS instrument with my working Standard Solutions of Suitable Concentrations and read the unknowns.
- Calculated % Content Using
- % Element =(readout from the ASS)*(Volume Used)*Dilution Factor
  - (Weight of Sample) * 10000
- The 10000 comes about from Unit Conversions
- %Element =(Mg/Kg*L*DF)

RESULT AND DISCUSSION

This section presents the results of four different sites of soil samples of lead content levels. The data was analyzed and is presented in forms of pie charts, tables, and graphs using Microsoft Office Excel 2013.

Table 1: Results of Lead Content levels from Different sites in Kabwe District in mg/kg.

Area	Makululu	Chowa	Mulungushi	Mukobeko
Sample 1	349.12	113,801.12	48.82	36.94
Sample 2	546.39	66789.79	24.55	42.99
Sample 3	950.98	89661.64	41.80	27.43

Note: 1mg/kg is equivalent to 1 ppm

In figure 1. The mean lead content levels from different sites in the Kabwe district are shown. Chowa had a higher mean lead content (90084.2 mg/kg lead soil content), this is followed by Makululu (615.5 mg/kg lead soil content), and the least lead content was in Mukobeko (35.79 mg/kg lead soil content).

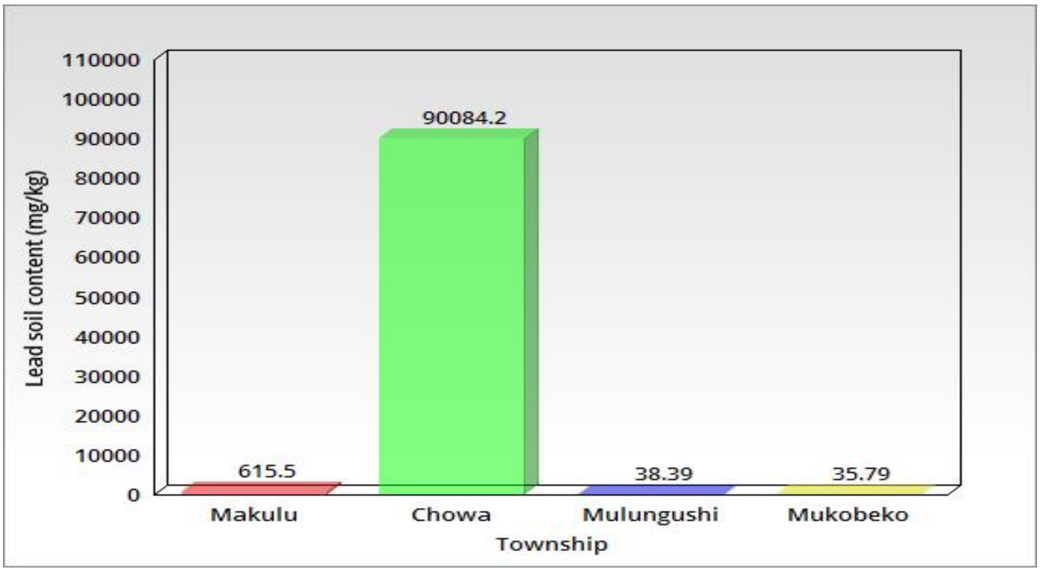

Figure 1: Mean Lead Content levels from Different sites in Kabwe District.

In figure 2. The percentage lead soil content for different sites in Kabwe: Makululu 0.06%, Chowa 9.01%, Mulungushi 0.0038 %and Mukobeko 0.0036%.

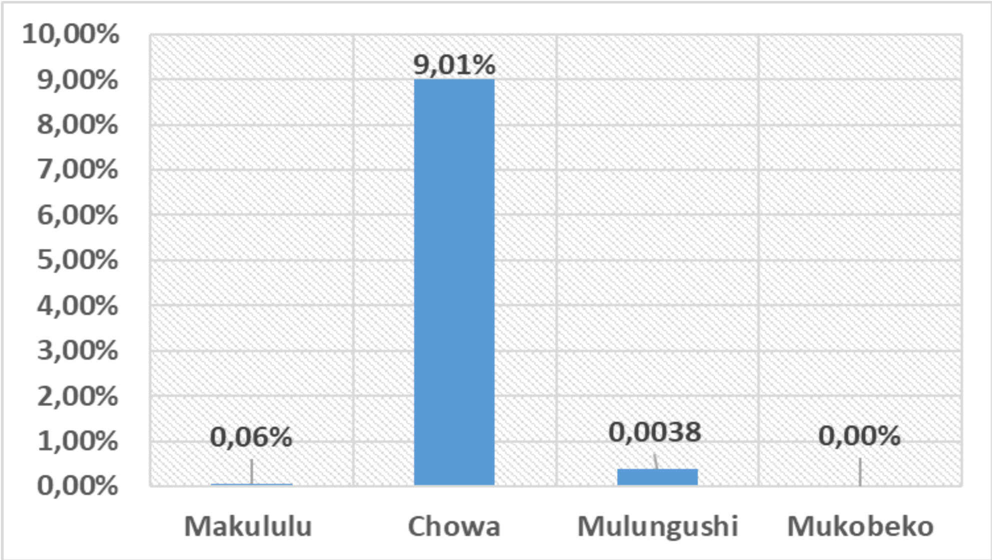

Figure 2: Showing percentage of Lead Content levels from Different sites in Kabwe District

Spectral characteristics of the site

Fig. 3 shows photos of some soil samples with their reflectance data from a study by Uchida (2017). The soil from site 005 was brighter in color, and its spectral data shows a marked difference compared with other soils. Moreover, soil samples from site 014 showed a different pattern. Based on personal communications, local people valued this soil as a relatively more fertile soil (called "black soil"), and the identification of this soil, when compared with other soils, seemed promising based on preliminary data from the current study. The data below 400 nm or above 900 nm showed large variabilities, but the data between these values (i.e., 400–900 nm) could be used to differentiate the soils. The influence of soil moisture was ignored since the soils were very dry, but future analyses should also focus on the effects of soil moisture.

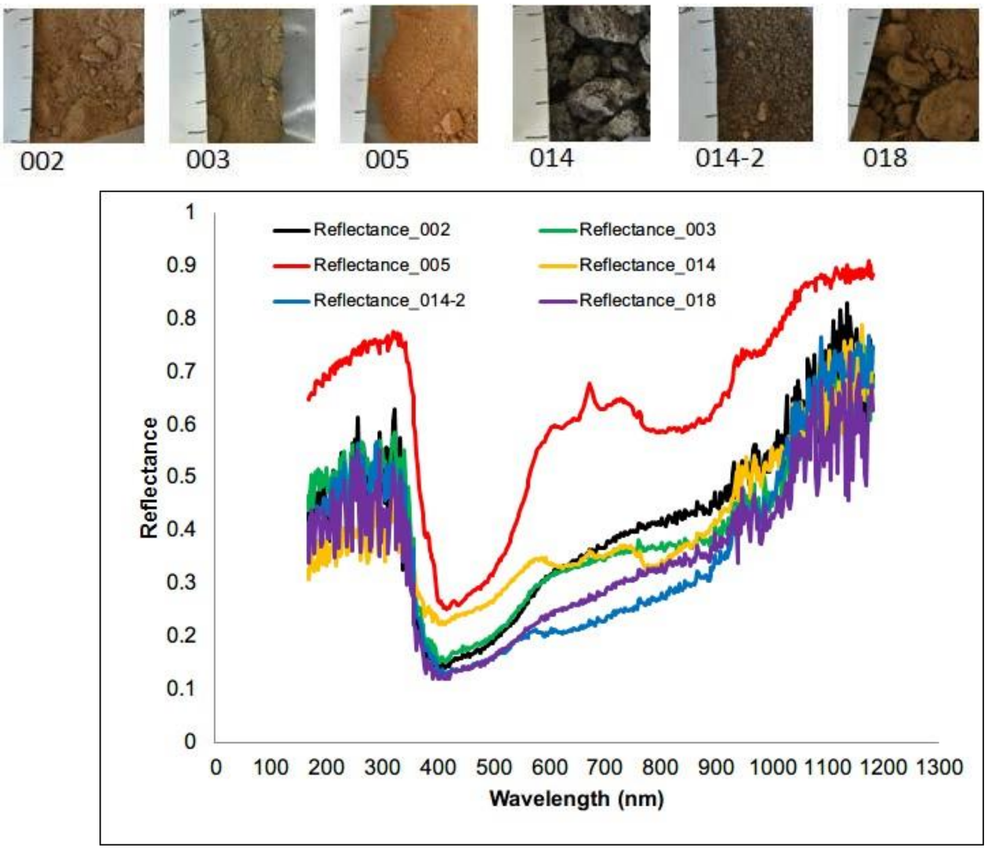

Figure 3. Photos of some of the sampled soils in Kabwe (top) and their reflectance (bottom)

The existing data establishes the severity of Pb exposure in Kabwe. Environmental data also support the observation that in certain housing areas of Kabwe, the recommended tolerable soil Pb level of 400 mg/kg is exceeded. The soil levels measured by Pure Earth 2014 are, in general, higher compared to those reported by KSDS in 2006. We suspect this results from enhanced granularity now available with a portable XRF (rather than an actual increase in concentrations).

The Geochemical soil analysis results of the 4 selected study sites showed that the chowa area was 90,084.20mg/kg, Makululu 615.50mg/kg, Mulungushi 38.39mg/kg, and Mukobeko at 35.79mg/kg. Chowa and Makululu soil lead content were above the prescribed residential area soil lead content by local authority Zambia environmental management Agency (ZEMA), the U.S. Environmental protection agency, and World Health Organisation(WHO) which stand at 400mg/kg or 400 parts per million (ppm). In the case of Chowa, it also exceeded the non-residential prescribed of 1200mg/kg or ppm making it of great concern seeing that people inhabit this area: despite the introduced law in Zambia prohibiting residing in areas with high lead content due to proximity to the old lead mine (Gulson et al., 1994). The distance from the source of contamination concerning the concentration and/ or distribution of the heavy metal in the soil and the increased effects concerning toxicity can be compared to a study done in China, looking at the distribution of heavy metal pollution (Radziemska & Fronczyk, 2015). This is also consistent with a similar study conducted in order to determine (i) the spatial extent of soil Pb as a function of distance from the Kabwe Pb and Zn mine (ii) the strength and direction of any relationship between lead concentration and soil texture and soil pH. A total of 37 topsoils (0-20cm) samples were collected by stratified random sampling from strata created at 7.5km, 9.5Km, and 12.5Km southeast of the mine. Soil lead was determined by using the Aqua Regia method, pH by the electrometric method, and soil texture by the hydrometer method. The measured lead concentration was found not to conform to the normal distribution for undisturbed environments. The results also showed that lead concentration decreased with an increase in distance in the southeastern direction (Hipkins, 1998; Lanphear, Succop, Roda, Henningsen, 2003)

Mulungushi and Mukobeko have low soil Lead content but may not be safe from pollution due to the movement of humans and machinery from areas of high lead soil pollution to these areas. Even vehicles are potential carriers of contaminated soil particles from areas of high pollution to areas of low pollution, as found by a study done in Poland. Therefore, there is a need to find ways of keeping pollution at a low in these areas (Chiluba, 2019 & Nagao et al., 2019; Haefliger, 2009). In conclusion, the Chowa area poses a health risk due to Lead Toxicity/poisoning, especially in children and childbearing mothers, who the effect is high and the rest of the human population in this area.

CONCLUSION

The findings of this study indicate that in all the four different areas of Kabwe district sampled for assessment of Lead soil content Levels. Chowa area soil lead Level of 90,084.20 mg/kg and Makululu of 615.50mg/kg exceeded the WHO limit for residential areas pegged at 400mg/kg. Moreover, Chowa further exceeded the prescribed non-residential lead soil content by WHO of 1200mg/kg.

The soil samples assessed were not adequate to represent the whole lead soil content levels in the Kabwe district. Further studies on the assessment of lead soil content need to be conducted on a larger scale to cover all areas in Kabwe.

- Samples at a much lower level into the ground should be tested as well than surface soil samples used in the study.
- Plants that reduce lead soil content should be promoted to be grown in Kabwe, such as *Amaranthus dubius Mart.*

REFERENCE

Agency for Toxic Substances and Disease Registry (ATSDR)(1988). The nature and extent of lead poisoning in children in the United States.A report to Congress.

Agency for Toxic Substances and Disease Registry (ATSDR)(1992). Toxicological profile for lead;1992. ATSDR/TP:88/17.

Agency for Toxic Substances and Disease Registry (ATSDR) (1990). Case studies in environmental medicine. Lead toxicity.

American Academy of Pediatrics (AAP)(1993). Committee on Environmental Hazards and Committee on Accident and Poison Prevention of the American Academy of Pediatrics. Statement on childhood lead poisoning. Pediatrics; 79/457-65.

Annette PU, Lorna F, Philip J. Landrigan, José L.M.(2000) "Lead exposure .charpter 19-WHO.

Budd (1998). The chemistry of metals.458 p.

Chiluba BC. (2019). The Finnish Sustainable Development of Water and Sanitation; A Case Study Insights for The Lusaka Water And Sanitation System Of Zambia. *International Journal of Advanced Research and Publications (3)4: 74-79*

Dooyema CA, Neri A, Lo YC, Durant J, Dargan PI, Swarthout T, Biya O(2010).The outbreak of fatal childhood lead poisoning related to artisanal gold mining in northwestern Nigeria.

Fauci AS (2008). Harrison's principles of internal medicine.17th edition. United states Mc Graw-hill professional.

Flegal AR(1995). Smith DR. Lead in the Biosphere. Recent Trends;1995

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https://journalkeberlanjutan.com/index.php/ijesss

Gulson BL, Mizon KJ, Law AJ, Korsch MJ, Davis JJ, Howarth D.(1994). Source and pathways of lead in humans from the Broken Hill mining community: alternative use of exploration methods. Econ Geol1994; 89: 889-908.

Haefliger P, Mathieu N, Lociciro M, Ndiaye S, Coly C, Diouf MA.(2009). Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal.Environmental Health Perspectives:117(10).

Hipkins KL, Materna BL, Kosnett MJ, Rogge JW, Cone JE.(1998) Medical Surveillance of the Lead Exposed Worker. AAOHN Journal 46(7): 330-339, 1998.

Katzung BG. (2006). Basic and clinical pharmacology. 10th edition. San Francisco: Mc Clow Hill Lange.

Lanphear BP, Succop P, Roda S, Henningsen G. (2003). The effect of soil abatement on blood lead levels in children living near a former smelting and milling operation. Public health Rep 2003; 118: 83-91

Mathee A, Naicker N, & Barnes B. (2009). Blood lead levels in South African children at the end of the leaded petrol era. Preliminary Research Report. Johannesburg: Medical Research Council.

Nagao N. Broadhurst JL. Educa S. Awere KG. Chiluba BC. (2019). Sustainable development in Africa: concepts and methodological approaches. Edition. USA: Spear Media Publications. Chapter number: Sustainability of Community and Mine Workers' Health in a Mining Context: A Rapid Review of Sustainable Development and Livelihoods; p 119 – 132

Needleman HL(1990). The long-term effects of exposure to low doses of lead in childhood. An 11-year follow-up report. N Eng J Med 322(2:83-8.

Radziemska M and Fronczyk J (2015). level and contamination assessment of soil along an expressway in the ecologically valuable area in central Poland. *Int j Environ Res Public health (10):13372 DOI:10.3390/ijerph121013372*

Von LI, Spalinger S, Petrosyan V, Von BP, Succop P, Roda S, Henningsen G. (2003). The effect of soil abatement on blood lead levels in children living near a former smelting and milling operation: Public Health Rep;2003. 118: 83-91.

Wallace AH (2001). Principles and Methods of Toxicology. 4th edition.

40 CFR Part 745 (2012). Lead; identification of dangerous levels of lead; final rule. Washington: U.S. Environmental Protection Agency; 2001. Available from: http://www.epa.gov/EPA-TOX/2001/January/Day-05/t84.[accessed 17 September 2012].