PARAMOUNT ECOLOGICAL RESOURCES

A Publication of PER https://paramountecologicalresources.com/

Review

RISK ASSESSMENT INDICES FOR HEAVY METALS CONTAMINATED WILDLIFE HABITAT

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Received 20th December, 2021
Accepted for publication 30th January, 2022
Published 12th March, 2022

Recommended citation: Egwumah F.A., Egwumah A.J., and Egwumah P.O. (2022). Risk Assessment Indices for Heavy Metals Contaminated Wildlife Habitat, *Paramount Ecological Resources*, 6 (1):1-13.

Abstract

Heavy metal may enter into wildlife habitat through diverse sources such as automobile emissions, industrial releases and further activities. Exposure to heavy metal poisoning can affect the proper functioning of nervous structure which is made up of the spinal cord and brain in some wildlife species. It can equally cause compilation of distorted blood cells in animal tissues resulting to serious pain and organ weakening such as lungs, kidneys and liver coupled with other essential body part in wildlife species. The basic processes stimulating entry of heavy metals into the body of wildlife species can take two steps namely; contact and actual entry. The representation of the prospect of serious health effects in wildlife species, due to exposure to dangerous ecological components can best be described as wildlife health risk assessment. However, hazard identification, assessment of dose-response, assessment of level of exposure and risk characterization are basic steps involves in wildlife health risk assessment, but concentration of non-essential metals in soils in wildlife habitat can be assessed using geoaccumulation index. Enrichment factor technique can be used to measure areas contaminated with atmospheric aerosols, solid wastes, soil and sediments. Pollution index can be adopted in order to assess the level of heavy metals in wildlife habitat and composite index method can also be used to evaluate the quality of soils in wildlife habitat. Similarly, risk factor can be used as an indicator to measure water pollution, quality of sediments and soils in wildlife habitats. Therefore, it is imperative to increase the understanding of wildlife health risks assessment, as a precedence in wildlife habitat management due to nonstop increase in concentration of heavy metals in wildlife home range. Operational supervision of habitat utilized by wildlife species may stimulate vital influences towards supportive advancement in biodiversity conservation.

Keywords: risk assessment; wildlife health; anthropogenic activities; heavy metals; wildlife habitat; pollution

INTRODUCTION

Any area with biological and ecological features where wildlife species has adjusted to due to the presence of basic necessities of life such as water, food, shelter, and mates for reproductive ventures can be described as habitat (Jedlikowski *et al.*, 2016). It can be grouped into following according to Casas *et al.* (2016), namely: forest habitats, non-forest habitats and aquatic habitats. Forest habitat can be defined as an area enclosed largely with green plants such as tree species with clear demarcation of layering and understory. Even if the forest has suffered some level of disturbance such as discriminate felling of trees and wildfire, it is equally defined as a forest habitat even with this forest gap, because there is still some anticipation of it regeneration into a forest in the nearest future (Czerepko *et al.*, 2021).

Non-forest habitats can be defined as areas enclosed with scrub, shrubs, grass, otherwise a mixture of numerous plant varieties. This type of habitat is famous for only one stratum. For instance, stunted undergrowth layers are common characteristics of non-forest habitats (Bobiec *et al.*, 2018). Aquatic habitat can be defined as areas that are perpetually or periodically enclosed by water and there is a strong difference between areas enclosed by bare-ground, to grasslands, undergrowth and etc or a mixture of several plants categories. Any habitat that is flooded does not fall into the categories of aquatic habitats (Lefebvre, *et al.*, 2019). Elements that are necessary for the day-to-day survival of the wildlife species are made available by all habitat but there is a great variation in the various types of habitats with respect to their multiplicity in terms of structural essentials associated with it.

However, several significant protected areas have been developed globally in recent decades due to growing appreciation of nature protection among the populace and government (Herzog, 2013). In Nigeria, ten new National parks have been established by the federal government across the country. This brings the total number of National parks in Nigeria, to seventeen (Anokwuru, 2020) and these protected areas are currently serving as habitat for wildlife species.

As a result, the long-term survival of a protected area is highly dependent on how man-wildlife interactions are handled. Apart from the conventional circumstance of wild creatures being a component of the protected area's goals, there are a few other possibilities to consider. So, just as the wildlife management concept can address the management of introduced and possibly invasive species, or large predators that cause crop or vegetation damage outside and inside the protected area, the wildlife management concept can also address the management of species that cause crop or vegetation damage inside the protected area (Herzog, 2013) coupled with other anthropogenic activities that might introduce heavy metals into wildlife habitat.

Heavy metals can be generated into home range utilized by wildlife species, through diverse forms of accomplishments (Simone *et al*., 2012). In different trails and proceedings; heavy metals occur on earth's crust naturally coupled with different forms of its application. The use of gasoline and diesel fuels as a source of energy generates climate change related greenhouse gases. Heavy metals are notorious for their non-biodegradable form coupled with prolong biological half-live, making it difficult to be removed from the body of wildlife species (Afrifa *et al*., 2015).

Heavy metals can flow into wildlife habitat, but it is a function of the properties of the metal in question coupled with environmental factors influencing it. This paper focuses on the wildlife health risk assessment indices for heavy metals contaminated wildlife habitat to give a clearer picture of the various parameters used in heavy metal risk assessment in wildlife habitat and consequently, the implications of each risk assessment indices in wildlife conservation.

Heavy Metals in Wildlife Habitat

Heavy metal may enter into wildlife habitat through diverse sources such as automobile emissions, industrial releases and further activities (Afrifa *et al*., 2015). Air pollution is usually generated from automobile emissions due to utilization of fossil fuels from different sources including combustion oil and of coal in power generating machineries, waste management using incinerators, heat generation in accommodation utilized by tourist and equipment used in construction of facilities in protected areas. Exposure to danger can simply be defined as risk, whereas indices can be defined as a means of measurement (indicator) or regulatory principles.

Wildlife habitats are environment that is necessary for survival and conservation of wildlife species coupled with other biotic beings. The total surrounding of wildlife species can best be described as environment (Bankole, 2008) and wildlife species are component of the environment. They depend on this environment for their activities such as feeding, mating and reproduction, shelter, escape from predators, social gathering, salt licks and drinking water. Therefore, the environment performance biological roles, feed assemblage, and consumption. Physical environment of wildlife species springs from water, air and land to other regular resources such as mineral elements, sunlight, soil and ecosystems (Mustapha and Lawal, 2014). Heavy metals can be defined as any chemical elements that are metallic in nature with a fairly great density above 5 g/cm^3 with high prospect to cause cancer, due to their toxic nature even at little absorptions. A very good examples of heavy metals are; mercury (Hg), cadmium (Cd), arsenic (As) and chromium (Cr) and etc.

Effects of Heavy Metals on Wildlife Species

Exposure to heavy metal poisoning can affect the proper functioning of nervous structure which is made up of the spinal cord and brain in some wildlife species. It can equally cause compilation of distorted blood cells in animal tissues resulting to serious pain and organ weakening such as lungs, kidneys and liver coupled with other essential body part in wildlife species (Agency for Toxic Substance and Disease Registry [ATSDR], 2003b, 2004). Prolong exposure may stimulate skeletal, muscular, coupled with neurological degeneration to occur at a very slowly rate. Allergies may develop as a result of nonstop exposure to the aforementioned chemical elements, which are metallic in nature and can equally cause cancer (Agency for Toxic Substance and Disease Registry [ATSDR], 2007, 2008).

Through food web or food chain heavy metals may gathered and biomagnified in the body of wildlife species. However, in some cases, they are very vital for the survival of wildlife species but toxicity may set in, if the permissible limits are exceeded. This may affect reproductive fecundity and behavioural characteristics (Liu *et al*., 2015; Egwumah *et al*., 2017). Similarly, heavy metals may gain access into wildlife species by direct breathing, eating, and skin contact concentration, posing a threat to wild animals (Tang *et al*., 2013; Liu *et al*., 2015; Egwumah *et al*., 2017). Arsenic and its related compounds are capable of causing cancer to wildlife species (Li and Ding, 2007), whereas lead is known for their prospect to cause lead poisoning and harm to nervous structure which is made up of the spinal cord and brain coupled with immune function (Egwumah *et al*., 2017).

Decreased in wildlife species reproductive and growth can be connected to cadmium, if ingestion, even in minute amounts, can impair the physiology and health of birds and other wildlife species (Liu *et al*., 2015). Chronic dietary exposure to low quantities of methylmercury can damage bird reproductive processes (Frederick, 2010; Egwumah *et al*., 2017). Furthermore, faeces of wildlife species are excellent accumulator of heavy metals at a greater capacity (Egwumah *et al*., 2017) compares to food (Liu *et al*., 2015). Therefore, wildlife species that are migratory in nature could be responsible for transmission of pollutant to a new location ((Liu *et al*., 2015; Egwumah *et al*., 2017). If polluted soil output is linked to wildlife habitat, the resulted outcome may show symptoms of exposure and uptake, especially if wild animals utilize and feed closely to areas with high concentration of pollutants. The wildlife species may face a high risk, compare to utilizing and feeding homogeneously across its habitat (Colestock, 2007).

Distribution of bird species and nesting success has been used as bioindicator of pollution in different environments utilized by birds (Fair *et al*., 2003; Egwumah *et al*., 2017). Once the environment is the same, feeding becomes limited in bird species. In a contaminated home range, bioaccumulation of heavy metals from food web or food chain may occur in wildlife population, indicating local pollution (Egwumah *et al*., 2017). Offspring of wildlife species are excellent indicator of chronic exposure due to their delicate life process and great relationship between the amounts of food consumed during developmental stage. Therefore, bird nestling can be used to measure exposure in breeding sites (Egwumah *et al*., 2017). In bird species, negative impacts on embryo advancement, feasibility, and hatching are associated with chromium concentrations (Kler *et al*., 2014).

In prescribed amount of 50mg/kg in some wildlife species, chromium is necessary for them to function properly, especially in avian species as acclaimed by WHO, but once this threshold is exceeded, it becomes harmful (Egwumah *et al*., 2017). Reduction in egg weight, reproductive fecundity and poor hatchability, can be linked to mercury concentration in avian species. Similarly, rapid rise in kidney injuries, brain injuries, skeletal defects; fewer number of clutch sizes, inability of eggs to hatch, poor embryonic advancement, alterations in behaviour, neurologic signs of loss of strength, and deficient coordination, can be linked to mercury concentration in avian species (Resaee *et al*., 2005; Egwumah *et al*., 2017). Rise in aberrations in fish eggs, can be linked to the selenium quantity above 10mg/kg, but selenium quantity in fish above 15mg/kg may result to teratogenesis and inability of the fish to reproduce (Ohlendorf *et al*., 2008; Egwumah *et al*., 2017). This could be applicable to other aquatic wildlife species. In bird species, arsenic could cause teratogenic effects and chromosomal injury in their bone marrow cells (Egwumah *et al*., 2017).

Pollution of wildlife habitat by heavy metals is serious menace to wildlife conservation globally, because heavy metals differ from organic pollutants that are capable of undergoing biodegradation to reduce their toxic nature, but heavy metals are in capable of undergoing any form of degradation making their toxic nature to prolong in the body of wildlife species (Ukoha *et al.,* 2014). Natural water bodies such as stream, lakes and rivers utilized by wildlife species are associated with contaminants, because once there is excessive runoff in heavy metal polluted areas, this metals flow in suspension or solution to the downstream, because of their complex nature, and ability to bind with supplementary compounds in wildlife habitats. The metals sink into the lowest part of the ecosystems, and can easily be consumed by wild animals either directly from drinking water, from the natural water bodies or foraging on plants growing around the natural water bodies

Copper concentration in recently imported frozen fish contain more than the permissible limit for seas food as recommended by World Health Organization (WHO), whereas cadmium and iron values were less than approved limits (Udo and Arazu,2011; Ukoha *et al*., 2014). The magnitudes of human activities in natural water bodies can be measure using health risk assessment to confirm the hostile effects, toxic metals in natural water bodies pose to aquatic life, using simple indices or parameters.
Heavy metal pollution may emanate from processes that are natural occurring and anthropogenic actions, for examples

rock weathering, wearing of top soil due to physical agents (soil erosion), mining, discharge from industrial activities, metropolitan runoff, sewage overflows, application of chemical substance to control pest and diseases and air contamination effects (Ming-Ho, 2005; Simone *et al*., 2012). Although some wildlife species are more predisposed to pollutants in their home range compare to others, for a huge percentage of wildlife species, the most pronounced means of exposed to pollutants is through food and water. The basic chain for heavy metal contamination in wildlife species follows recurrent format: industries, atmosphere, water, foods, soils and wildlife species. However, the amount of toxic substance deposited in wildlife species is a function of the quantity consumed (Agency for Toxic Substance and Disease Registry [ATSDR], 2003b, 2004, 2007, 2008; Castro-González and Méndez-Armenta, 2008; Simone *et al*., 2012).

The basic processes stimulating entry of heavy metals into the body of wildlife species can take two steps namely; contact and actual entry. The contact is also described as exposure whereas the actual entry equally refers to crossing the borderline. Preoccupation of heavy metals whichever, upon crossing the borderline (Afrifa *et al*., 2015) or afterwards, may result to the presence of the quantity of chemical transferred to biological vital areas within the body of wildlife species. Intake and uptake processes are responsible for chemical substance to cross the borderline, basically from outside the body to inside the body of wild animals.

Direct movement of chemical substances through the physical openings such as nose (breathing or inhalation) and mouth (through eating of food or drinking of water) refers to intake (Afrifa *et al*., 2015). Under normal circumstances, these chemical substances are found in the basic components of the ecosystems. For examples; air, food, or water coupled with the concentration of the chemical substances in the body of wildlife species. These chemicals can only be estimated by the quantity that enters.

In this regard, mass transmission may take place by bulk flow coupled with the quantity of the contaminated substances actually moving over, which can best be ascribed as chemical intake rate (Afrifa *et al*., 2015). When toxic substances enter the body of wildlife species through the skin or eyes of wildlife species, it can be referred to as uptake.

However, these chemicals are found in a medium carrying them, but the medium as an entity is not absorbed at the same concentration as the chemicals. Therefore, the quantity of chemical crossing borderline cannot be approximated using the same principles of estimating intake.

Direct uptake across outside the borderline of wildlife's body is dermal absorption which follows actually contact, followed by entry and absorption. This process has been used to develop the equations which can be linked to exposure and dose with all the paths of exposures.

In soil pollution, the main wildlife health concern of heavy metal exposure to wildlife population is gathering of heavy metals over a long period resulting to bone disease and renal dysfunction especially, when food containing heavy metals are consumed (Syers and Gochfeld, 2000) especially in wildlife species that utilizes salt licks sites.

In wildlife management, toxic heavy metals have gain global recognition in recent time (Fenglian and Qi, 2011), due to bio-accumulation and bio-magnification prospect coupled with their ability to continue to exist within habitat of wildlife species. The following minerals elements are very essential, for example; cobalt (Co), copper (Cu) and zinc (Zn) for normal body growth and functions to take place in wildlife species. The best description for the aforementioned elements is essential elements.

The other elements not mentioned under this category are known as non-essential, and once their permissible limit is exceeded it becomes highly toxic to wild animals (Ouyang *et al.,* 2002). There is an ideal concentration of chromium necessary for normal body functions in wildlife species. However, high absorptions could result to toxicity effects like, liver and kidney related issues in wild animals coupled with genotoxic and carcinogen (Koki *et al.*, 2015). Mineral elements that are non-essential and highly toxic are; lead (Pb), chromium (Cr), manganese (Mn), and cadmium (Cd).

Just like chromium, cobalt is equally one of the basic elements required for normal body functions, and it is a vital element in vitamin B_{12} (Strachan, 2010). However, if cobalt is consumed at a very high concentration, through foraging items utilized by wildlife species, it might result to excessive synthesis of red blood cells, abnormal thyroid artery, polycythemia, and right coronary artery related issues (Robert and Mari, 2003).

However, increased concentration of manganese and copper in natural water bodies such as stream, lakes and rivers can pose a serious threat to wildlife habitat. If high rate of the aforementioned metals is absorbed in drinking water, it could result to mental diseases such as Alzheimer's and reduction in feed consumption, reduction in growth rate and lethargy (Dieter *et al.,* 2005). Wildlife species utilizing protected areas in metropolitan areas are not left out, because heavy metals in metropolitan soils coupled with dust generated by roads and railways may gathered on the body of wildlife species. In addition, through taking of oxygen, coupled with contact with the skin absorption, heavy metals may gain entry into the body of wildlife species (Ahmed and Ishiga 2006; De Miguel *et al.,* 2007). Apart from that, wild animals equally forage on crops, therefore through soil-crop collaborations wildlife species are exposed to heavy metals in farmlands (Liu *et al.,* 2007). From all indication, sources of heavy metal pollution in wildlife habitat are a function of anthropogenic activities and this is currently a crucial global challenge (Stezar *et al*., 2011).

Wildlife health risk assessment could be considered as a more appropriate measure to quantify the prospective danger contaminated wildlife habitat posed to wildlife species in their natural habitat due to diverse forms of land use and its associated risks. This may include the wild animal health and ecosystems (with ecological services inclusive), coupled with subsurface water flow (Swartjes *et al*., 2012). Over the years, this wildlife health risk assessment area has gain recognition with more researchers trying to find a lasting solution to heavy metal pollution in home range of wildlife species due to increase anthropogenic activities.

Potential Wildlife Health Risk Assessment

The representation of the prospect of serious health effects in wildlife species, due to exposure to dangerous ecological components can best be described as wildlife health risk assessment. It involves the application of engineering proceedings and statistics to detect and measure threats (USEPA, 2012), to define potential paths of exposure, and use the evidence obtained to estimate a statistical value to denote the prospective risk posed to wildlife species (Lushenko, 2010). However, hazard identification, assessment of dose-response, assessment of level of exposure and risk characterization are basic steps involves in wildlife health risk assessment.

Hazard Identification

The determination of the prospect of a specific chemical substance to be connected to a specific health effect or not can be described as hazard identification.

Dose-Response Assessment

In wildlife health risk assessment, mineral elements are categorized as teratogen, carcinogen, and a prospective mutagen (Burger, 2008). In calculating prospective risk, this categorization determines the procedure to follow. Teratogen are expected to have a threshold, below this threshold serious effects on wildlife health will not noticed. A component of the reference-dose (R_fD), is usually added as a fraction of hazard assessment.

In risk assessment of carcinogen, the basic hypothesis used is the prospect of cancer emerging with little doses of exposure. Therefore, cancer causing chemical lacks safe threshold in wildlife species. However, they are communicated using their cancer potency factor (Lushenko, 2010).

According to Kirsch-Volders *et al*., (2009), the threshold for prospective mutagen can be classified as follows: true threshold, threshold dose, practical threshold, biologically meaningful threshold and NOEL (the No Observed Effect Level).

True Threshold: This is the spot where there is an alteration in a slope of zero to a slope larger than zero in dose reaction linked to mutagenicity.

Threshold dose: This is the genuine dose, lower than this, there is no increase in effect above the related concentration. This threshold in particular is difficult to identify due to explicit serious practical related problems. Therefore, researchers prefer to derive practical threshold.

Practical Threshold: This is the spot where dose response connects, obtained from research findings supersedes the background changes in an excellent design and well executed research.

Biologically meaningful threshold: This is the threshold dose obtained from practical research work especially where there is backup evidence to decide that the action really occurs. In future risk assessment biologically, meaningful threshold could be of help in terms of credible explanation to threshold dose for mutagenicity.

The No Observed Effect Level (NOEL): The peak dose in a research work defines the no observed effect level, where there are no significant changes above parallel negatively control parameters using statistical proceedings. The NOEL is a function of experimental design, sample size, spacing in terms of dose, and method of data analysis adopted, etc. It is imperative for researchers in wildlife health risk assessment not to equate NOEL with threshold dose because absence of significant difference may represent a real, but fewer effect is beyond detection level. This should be noted when investigating heavy metals that are highly toxic to wildlife species.

Wildlife health risk evaluators should have it in mind that, other causes of endogenous mutation exist in wildlife habitats. Excellent examples of this processes are physico-chemical, free radicals and enzymatic. These processes may control DNA injury and replacement of worn-out tissues negatively because these tissues are responsible for unplanned mutation rate, which may likely demonstrate at the background (Morley and Turner, 1999).

Risk characterization

Risk characterization is an essential part wildlife health risk assessment process. Information from previous parts of the risk assessment is integrated coupled with synthesizes and total inference about accomplish risk. The information produce coupled with the usefulness of the information basically for decision making makes this process a vital component of wildlife health risk assessment.

First and foremost, in wildlife health risk assessment linked with foraging items, risk characterization can be carried out using Hazard Quotient (HQ) and Total Hazard Index (THI). This was formulated by USEPA (United States Environmental Protection Agency), resulting to the model given below (Agency for Toxic Substances and Disease Registry (ATSDR 2005).

D = (C x IR x AF x EF x CF) ÷ BW

Each of the formulas in this model are interpreted as follows:

D = exposure dose which can be measured in mg/kg/day bases on the quantity of food consumed by wildlife species;

C = this is the concentration of the contaminant in the food consumed by wildlife species and it is usually measured in mg/Kg;

IR = this is the intake rate of contaminated food by wildlife species measured in mg/day;

AF = this is the bioavailability factor and it has no unit;

EF = this is the exposure factor and it has no unit;

CF = this is the conversion factor measured in Kg/mg;

BW =this is the body weight of wildlife species expressed in Kg.

In wildlife health risk assessment, the risk of consuming heavy metal-contaminated food in wildlife habitat can also be characterized using Hazard Quotient (HQ). However, HQ can be defined as the ratio of determined dose to the reference dose (R_fD), mathematically, it can be calculated by dividing determined dose by the reference dose (R_fD).

If the ratio is less than one, it poses no risk to wildlife population but if the ratio is equal or greater than one wildlife population will be face with health risk (Khan *et al*., 2009). The aforementioned health risk assessment method has been utilized by Chien *et al*. (2002); Wang *et al*. (2005) and Sridhara *et al*. (2008) and they confirmed the effectiveness and accuracy of the model.

The following equation is used;

$HQ = [W_{plant}] \times [M_{plant}] / R_f D \times B$

Each of the formulas in this model are interpreted as follows:

$[W_{plant}]$ = this is the dry mass of contaminated plant species utilized by wildlife species as feeding items expressed in mgd^{-1};

$[M_{plant}]$ = this is the heavy metal concentration in the plant species utilized by wildlife species usually expressed in mg kg^{-1};

R_fD = this is the wildlife food reference dose for heavy metal concentration usually expressed in mgd^{-1};

B = this is the body mass of wildlife species expressed in kg.

However, R_fD values for heavy metal concentration in wildlife species can be obtained from United State Environmental Protection Agency and Department of Environment, Food and Rural Affairs (Khan *et al*., 2009) coupled with Integrated Risk Information System (Abdollatif *et al*., 2009) especially for developing nations without proper wildlife health risk assessment guidelines.

Exposure assessment

Wildlife species can easily be expose to heavy metals direct in their natural habitat through soil. However, this may take three exposure pathways (Lai *et al*., 2010), namely; direct ingestion of soil through salt licks; breathing of polluted air particles emitted from soil and dermal absorption of contaminants through contact with the skin.

In risk assessment of carcinogen, the basic hypothesis used is the prospect of cancer emerging with little doses of exposure. Therefore, cancer causing chemical lacks safe threshold in wildlife species. However, they are communicated using their cancer potency factor (Lushenko, 2010).

Bearing in mind, the diverse adverse health effects of heavy metals on wildlife health as mentioned above, non-carcinogenic and carcinogenic risks assessment in wildlife species can be calculated (USEPA, 2012).

In order to calculate hazard exposure in offspring and adults of wildlife species, the model given below can be adopted for non-carcinogenic hazard risk (Zhang *et al.,* 2012).

$$CDI_{ing-nc} = \frac{C \times IngR \times EF \times ED}{BW \times AT_{nc}} \times 10^{-6}$$ (Zhang *et al*., 2012)

$$CDI_{inh-nc} = \frac{C \times EF \times ET \times ED}{PET \times 24 \times AT_{nc}}$$ (Rahman *et al*., 2012)

$$CDI_{dermal-nc} = \frac{C \times SA \times AF \times ABSd \times EF \times ED}{BWT \times AT_{nc}} \times 10^{-6}$$ (Shi *et al*., 2014)

$$HQ = \frac{CDI\ nc}{RfD}$$

$HI = \sum HQ = HQ_{ing} + HQ_{inh} + HQ_{dermal}$ (Shi *et al*., 2014)

In order to assess the carcinogenic hazard risk in wildlife home range, chemical substance that are carcinogenic, such as Cd, Cr, Ni and Pb should be put into consideration (Total Risk) using Equations below (Shi *et al*., 2014):

$$CDI_{ing\text{-}ca} = \frac{CX\ IR\ X\ EF}{AT_{ca}} X\ 10^{-6}$$

(Yaylali-Abanuz, 2011).

$$IR = \frac{ED_{offspring}\ x\ Ing\ R_{offspring}}{BW_{offspring}} + \frac{ED_{adult} - ED_{offspring}\ x\ Ing\ R_{adult}}{BW_{adult}}$$

(Loska *et al*., 2004).

$$CDI_{inh\text{-}ca} = \frac{C\ x\ EF\ x\ ET\ x\ ED}{PET\ x\ 24\ x\ AT_{ca}} x\ 10^{-6}$$

(Shi *et al*., 2014).

$$CDI_{dermal\text{-}ca} = \frac{C\ x\ ABS_d\ x\ ET\ x\ DFS_{adj}}{AT_{ca}} x\ 10^{-6}$$

(Lai *et al*., 2010).

$$RISK = CDI_{ca}\ x\ CSF$$

(Shi *et al*., 2014).

$$TOTAL\ RISK = RISK_{ing} + RISK_{inh} + RISK_{dermal}$$

(Shi *et al*., 2014).

$$CDI_{ing\text{-}ca}\ x\ CSF_{ing} + CDI\ x\ IUR + \frac{CDI_{dermal\text{-}ca}\ x\ CSF_{ing}}{ABS_{GI}}$$

(Shi *et al*., 2014).

Where;

CDI_{ing}, CDI_{inh}, CDI_{dermal} = this is refers to the prolonged intake on daily basis or dose obtained through contact with the skin, food (mg/kg/d), breathing (mg/m^3) for non-cancer and μg/m^3 for cancer) and wildlife skin contact with contaminated soil particles (mg/kg/d), respectively.

R_fD = This is the reference dose, and R_fD (chronic oral reference dose), R_fC_{inh} (chronic inhalation reference concentration), RdD_{dermal} (chronic dermal reference dose, $RfD_{ing} \times ABS_{GI}$) via three exposure routes. *CSF* was the chronic slope factor, including *CSF*, *IUR*, CSF_{dermal} *GI* for different exposure pathways. CSF_{dermal} could be calculated by CSF_{ing} / ABS_{GI}

Contamination levels of Heavy metals in the soils in Wildlife Habitat using Geoaccumulation

Concentration of non-essential metals in soils in wildlife habitat can be assessed using geoaccumulation index (I). However, this method has gain high level of recognition over the years from the period Muller developed it in the year 1969 as cited by Wei and Yang, (2010), and the I_{geo} can be adopted to measure the level of heavy metal pollution in forest soil by comparing between current soil condition and pre-ecological tourism concentrations. However, it could be difficulty to obtained pre-ecological tourism concentrations sediment layers. In Geoaccumulation index the model stated below is usually adopted (Wei and Yang, 2010):

$$I_{geo} = Log_2 (C_n / 1.5B_n)$$

From the model;

C_n = this is the concentration of environmental elements measured,

B_n = this is the geochemical soil background. However, the value of the constant used to analyse the changes in concentration of element in wildlife habitat is 1.5, in order to identify minor anthropogenic effect (Ji *et al*., 2008; Wei and Yang, 2010). Muller (1969) as cited by Wei and Yang, (2010), came up with calculation and classification of the I_{geo} for different heavy metals. They calculated and classified chemical substance as follows: uncontaminated (I_{geo} is less than or equal to 0); uncontaminated to moderately contaminated (0 is less than I_{geo}, but I_{geo} is less than or equal to 1); moderately contaminated (1 is less than I_{geo} but I_{geo} is less than or equal to 2); moderately to heavily contaminated (2 is less than I_{geo} but I_{geo} is less than or equal to 3); heavily contaminated (3 is less than I_{geo} but I_{geo} is less than or equal to 4); heavily to extremely contaminated (4 is less than I_{geo}, but I_{geo} is less than or equal to 5); extremely contaminated (I_{geo} greater than or equal to 5).

Enrichment Factor

In heavy metal pollution assessment in marine habitat (natural water bodies). Data of pre-industrial metal concentrations are usually used as a reference with respect to the newly measured values, in order to compare (Abrahim and Parker, 2008). Therefore, to obtain a comprehensive information on sediment quality in the bay interior, different techniques of environmental assessment could be adopted to determine heavy metal concentrations. A very good example is the "enrichment factor (EF)" used to create a distinction between anthropogenic and natural resources of heavy metals incident (Özkan, 2012). Enrichment factor technique can be used to measure areas contaminated with atmospheric aerosols, solid wastes, soil and sediments to measure the level of alteration in the composition (Pekey, 2006).

Enrichment factor (EF) of metal can be defined by adopting aluminium as a reference element.

$$EF = \frac{(C\ x/C_{Al})\ Sample}{(Cx/C_{Al})\ background}$$

$(C\ x/C_{Al})$ = the ratio of concentration of aluminium present in the sample and

(C_x/ C_{Al}) = background is the ratio of concentration of aluminium present in background of the sample.

Using the aforementioned formula, the background concentrations of iron, manganese, copper, zinc, lead, mercury, chromium, cadmium and aluminium in ordinary shale found in wildlife habitat can be obtained (Özkan, 2012).

Birch (2003) separated prospective pollutants into dissimilar groups established on EF values. For instance; EF values less than 1 reveals "no enrichment", EF values less than 3 is "minor enrichment", EF values equal to 3-5 is "moderate enrichment", EF values equal to 5-10 is "moderately severe enrichment", EF values equal to 10-25 is "severe enrichment", EF values equal to 25-50 is "very severe enrichment" a d EF values greater than 50 is "extremely severe enrichment".

Heavy metal pollution assessment

In order to assess the level of heavy metals in wildlife habitat pollution index (PI) can be adopted. Using the equation stated below, pollution index (PI) of each metal can be ascribed to each metal (Wei *et al*., 2009):

$PI = C_n / B_n$

In the aforementioned equation, C_n (mg/kg) represent concentration measured of each heavy metal whereas B_n represent each metal background value.

The PI of every metal can be categorised as either low (P less than or equal to 1), moderate (1 less than PI less than or equal to 3) or high contamination (PI is greater than 3).

Pollution Evaluation Method

In order to evaluate the quality of soils in wildlife habitat, composite index method (Nemerow Index) can be used (Liang *et al*., 2011). In this method, a single pollution index, that are capable of reflecting further, nonstop pollution as a form of environmental indicators.

The composite index method used the formula stated below;

$$\text{Single Pollution Index } (Pi) = Ci/Cref$$

(Liang *et al*., 2011)

From the equation stated above,

Pi = represents the single pollution index;

C_i = represents the average quantities of heavy metals from selected wildlife habitat sites;

Cref = this the assessment criteria values.

However, for developing nations without specified recommendation for heavy metals pollution in soil, evaluation criteria values suggested for cultivated soil by the Canadian Council of Ministers for the Environment in the year 2007 as cited by Liang *et al*. (2011) can be adopted. In Nemerow Composite Index method, each assessment factors are put into consideration and the importance of the pollutants are highlighted (Liang *et al*., (2011).

$$\text{Nemerow Index } (P_s) = \sqrt{(P_{ave}^2 + P_{max}^2) / 2}$$

From the equation stated above,

P_{ave} = mean of single pollution index for all heavy metals under evaluation;

P_{max} = peak value of the single pollution index for all heavy metals under evaluation.

In order to measure the soil quality, the quality of soil environment can be put into consideration in wildlife habitat. The maximum is classified into 5 grades based on Nemerow pollution index: (P_s less than 0.7, safety domain; 0.7 less than or equal to P_s but less than 1.0, precaution domain; 1.0 equal to P_s but less than 2.0, slightly polluted domain; 2.0 equal to P_s but less than 3.0, moderately polluted domain; and P_s less than 3.0, extremely polluted domain (Liang *et al*., 2011).

Apart from that, the prospective ecological risk index technique offered by Hakanson as cited by Ogunkunle and Fatoba, (2013), forms one of the ways to assess soils in wildlife habitat with respect to concentration of heavy metals coupled with its related ecological and environmental properties, if the toxic nature of the metals are put into consideration (Qingjie *et al*., 2008). However, the risk factor can be used as an indicator to measure water pollution, quality of sediments and soils. From all indication, a very high rate of success has been recorded so far with respect to assessment of heavy metals pollution (Ogunkunle and Fatoba, 2013). This method can equally be used to measure water pollution, quality of sediments and soils in wildlife habitat. The equation for ecological risk index is stated below:

$$RI = \sum_{i=`1}^{n} E_r^i ; E_r^i = T_r^i \times Pi$$

(Ogunkunle and Fatoba, 2013).

Where;

E_r^i = potential ecological risk for each coefficient;

T_r^i = the toxicity reaction coefficient of metals and their toxic nature as established by Hakanson as cited by Ogunkunle and Fatoba, (2013). The toxicity reaction coefficients for some metals are stated below with their toxicity reaction coefficients in parenthesis, for examples; lead (5), copper (5), chromium (2), cadmium (30), and zinc (1). However, the indices of prospective ecological risks (Ogunkunle and Fatoba, 2013) are stated in Table 1 below.

Table 1: risk of grades of single and comprehensive ecological risk of heavy metal Pollution.

E_r	A particular prospective ecological risk E_r	RI	All-inclusive prospective ecological risk (RI)
<40	Small prospective Ecological risk	<90	Small prospective Ecological risk
$40 \leq E_r < 80$	Modest prospective risk	$90 \leq RI \leq 180$	Modest ecological risk
$80 \leq E_r < 160$	Significant prospective risk	$180 \leq RI < 360$	Strong potential ecological risk
$160 \leq E_r < 320$	Great prospective risk	$360 \leq RI < 720$	Very strong prospective
≥ 320	Considerably very strong	≥ 720	High- strong prospective

CONCLUSION AND RECOMMENDATIONS

Conclusion

The overall view of some risk assessment indices for heavy metal contaminated wildlife habitats are provided in this in this paper to enable us know the various techniques and indices that can be adopted in wildlife health risk assessment. Therefore, it is imperative to increase the understanding of wildlife health risks assessment, as a precedence in wildlife habitat management due to nonstop increase in concentration of heavy metals in wildlife home range with respect to increased anthropogenic activities.

Therefore, operational supervision of habitat utilized by wildlife species may stimulate vital influences towards supportive advancement in biodiversity conservation as anthropogenic activities are increases on daily basis. The actual management of wildlife habitat in an effective manner is a function of the populace, ability of institutions to build man power, and establish inform campaign of ecological benefits provided by wildlife species to human well-being.

Recommendations

Rapid advancement of molecular biological techniques becomes imperative to bring appreciated benefits to wildlife analytical field in order to promote continuous monitoring of home range of wildlife species. Consistency in method of data gathering, investigation, legislation and regulations should be considered in the use of pollution and toxic substances assessment in the wildlife habitat as indices to measure wildlife health risk to ensure accuracy of predictions of effects of heavy metals on wildlife health.

REFERENCE

Abdollatif G. A., Ardalan M., Mohammadi M.T., Hosseini H.M. and Karimian N. (2009). Solubility Test in Some Phosphate Rocks and their Potential for Direct Application in Soil. *World App. Sci. J*., 6(2): 182-190.

Abrahim, G.M.S. and Parker, R.J. (2008). Assessment of heavy metal enrichment factors and degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. *Environmental Monitoring and Assessment*, 136: 227- 238.

Afrifa C. G., Ofosu F. G., Bamford S. A., Atiemo S. M., Aboh I. J. K., Gyampo O., Ahiamadjie H., Adeti J. P. and Arthur J.K. (2015). Health Risk Assessment of Heavy Metal Exposure from Soil Dust at Selected Fuel Filling Stations in Accra. *International Journal of Science and Technology* Volume 4 No. 7, 289- 296.

Agency for Toxic Substance and Disease Registry (ATSDR). (2003b). Toxicological Profile for Mercury U.S. Department of Health and Humans Services, Public Health Humans Services, Centers for Diseases Control. Atlanta.

Agency for Toxic Substance and Disease Registry (ATSDR). (2007). Toxicological Profile for Lead U.S. Department of Health and Humans Services,Public Health Humans Services, Centers for Diseases Control. Atlanta.

Agency for Toxic Substance and Disease Registry (ATSDR). (2008). Draft Toxicological Profile for Cadmium U.S. Department of Health and Humans Services, Public Health Humans Services, Centers for Diseases Control. Atlanta.

Agency for Toxic Substances and Disease Registry (ATSDR 2005), Public Health Assessment Guideline Manual Available at http://www.epa.Gov/iris/indes hmtl.

Agency for Toxic Substances and Disease Registry (ATSDR). (2004). Toxicological Profile for Copper. U.S. Department of Health and Humans Services, Public Health Service, Centers for Diseases Control. Atlanta.

Ahmed F. and Ishiga H. (2006) .Trace metal concentrations in street dusts of Dhaka city, *Bangladesh, Atmospheric Environment* 40:3835 –3844.

Anokwuru, E. (2020). Nigeria opens 10 new National Parks https://www.sunnewsonline.com/nigeria-opens-10-new-national-parks/ Accessed 4th January, 2022.

Bankole, O.P. (2008). "Major environmental issues and the need for environmental statistics and indicators in Nigeria," in Proceedings of the ECOWAS workshop on Environmental Statistics, Abuja, Nigeria.

Birch, G., ed. C.D.a. Woodroffe, F. (2003). Coastal GIS 2003, Wollongong University Papers in Center of Maritime Policy, 14, Australia, Edition edn.

Bobiec, A., Reif, A., & Öllerer, K. (2018). Seeing the oakscape beyond the forest: a landscape approach to the oak regeneration in Europe. *Landscape Ecology*, *33*(4), 513–528.

Burger J. (2008). Assessment and management of risk to wildlife from cadmium. *Sci Total Environ*. Jan 15; 389(1):37-45. doi: 10.1016/j.scitotenv.2007.08.037. Epub 2007 Oct 29. PMID: 17910979.

Casas, G., Darski, B., Ferreira, P. M. A., Kindel, A., & Müller, S. C. (2016). Habitat structure influences the diversity, richness and composition of bird assemblages in successional Atlantic rain forests. *Tropical Conservation Science*, *9*(1), 503–524.

Castro-González, M.I. and Méndez-Armenta, M. (2008). Heavy metals: Implications associated to fish consumption. Environmental Toxicology and Pharmacology, 26, 263-271.

Chien, L.C., Hung T.C., Chaong K.Y., Yeh C.Y., Meng P.J and Shieh (2002). Daily intake of TBT, Cu, Zn, Cd, and as for fishermen in Taiwan. *Sci. Total Environ*., 285: 177-185.

Colestock KL (2007) Landscape scale Assessment of Contaminant effects on Cavity Nesting Birds. MSc Thesis Utah State University, Logan Utah, USA, pp.1-8.

Czerepko, J., Gawryś, R., Szymczyk, R., Pisarek, W., Janek, M., Haidt, A., Kowalewska, A., Piegdoń, A., Stebel, A., & Kukwa, M. (2021). How sensitive are epiphytic and epixylic cryptogams as indicators of forest naturalness? Testing bryophyte and lichen predictive power in stands under different management regimes in the Białowieża forest. *Ecological Indicators*, *125*, 107532.

De Miguel E., Irribarren I., Chacón E., Ordoñez A. and Charlesworth S. (2007). Risk-based evaluation of the exposure of children to trace elements in playgrounds in Madrid (Spain), *Chemosphere* 66: 505– 513.

Dieter HH, Bayer TA, Multhaup G (2005). Environmental copper and manganese in the pathophysiology of neurologic diseases (Alzheimer's disease and Manganism), *Actahydroch. hydrob*. 33:72-78.

Egwumah FA, Egwumah PO, Edet DI (2017) Paramount Roles of Wild Birds as Bioindicators of Contamination. *Int J Avian & Wildlife Biol* 2(6): 00041. DOI: 10.15406/ijawb.2017.02.00041.

Fair J, Myers OB, Ricklefs RE (2003) Immune and growth response of Western bluebirds and Ash-throated Flycatchers to soil contaminants. *Ecological Applications* 13: 1817-1829.

Fenglian Fu, Qi W (2011). Removal of Heavy Metal ions from Waste Waters: A review. *J. Environ. Manage*. 92(3):407-418.

Frederick P, Jayasena N (2010) Altered pairing behaviour and reproductive success in white ibises exposed to environmentally relevant concentrations of methylmercury. *Proceeding of Royal Society Biological Sciences* 278: 1851-1857.

Herzog, S. (2013). Wildlife Management in Protected Areas - Goals and Concepts 5th Symposium Conference Volume for Research in Protected Areas held in Mittersill, Austria, pages 295-298.

Jedlikowski, J., Chibowski, P., Karasek, T., & Brambilla, M. (2016). Multi-scale habitat selection in highly territorial bird species: exploring the contribution of nest, territory and landscape levels to site choice in breeding rallids (Aves: Rallidae). *Acta Oecologica*, *73*, 10–20.

Ji Y., Feng Y., Wu J., Zhu T., Bai Z., Duan C. (2008). Using geo-accumulation index to study source pro files of soil dust in China, *Journal of Environmental Sciences* 20 (2008) 571 – 578.

Khan S., Farooq R., Shahbaz S., Khan M.A. and Sadique M. (2009). Health Risk Assessment of

Heavy Metals for Population via Consumption of Vegetables. *World Applied Sciences Journal* 6 (12): 1602-1606.

Kirsch-Volders M, Vanhauwaert A, Eichenlaub-Ritter U, Decordier I. (2003). Indirect mechanisms of genotoxicity. Toxicology Letters 140-141:63-74.

Kler TK, Vashishat N, Kumar M (2014) Heavy metal contamination in excreta of avian species from Ludhiana district of Punjab. International Journal of Advanced Research 2(7): 873-879.

Koki I.B, Bayero A.S, Umar A. and Yusuf S. (2015). Health risk assessment of heavy metals in water, air, soil and fish. *African Journal of Pure and Applied Chemistry* Vol. 9(11), pp. 204-210.

Lai, H.-Y.; Hseu, Z.-Y.; Chen, T.-C.; Chen, B.-C.; Guo, H.-Y.; Chen, Z.-S. (2010). Health risk-based assessment and management of heavy metals-contaminated soil sites in Taiwan. *Int. J. Environ. Res. Publ. Health, 7,* 3595–3614.

Lefebvre, G., Davranche, A., Willm, L., Campagna, J., Redmond, L., Merle, C., Guelmami, A., & Poulin, B. (2019). Introducing WIW for detecting the presence of water in wetlands with landsat and sentinel satellites. *Remote Sensing*, *11*(19), 2210.

Liang, J., Chen, C., Song, X., Han, Y. and Liand, Z. (2011). Assessment of Heavy Metal Pollution in Soil and Plant from Dunhua Sewage Irrigation Area, International Journal of Electrochemical Science, 6, 5314-5324.

Li F, Ding CQ, (2007) Effects of heavy metal pollution on birds. *Acta Ecologica Sinica* 27: 296-303.

Liu J, Xingzhong JL, Guangming Y, Yuan ZY, Wu H, et al. (2015) An integrated model for assessing heavy metal exposure risk to migratory birds in wetland ecosystem: A case study in Dongting Lake Wetland. China Chemosphere (135): 14-19

Liu W.X., Shen L.F., Liu J.W., Wang Y.W., Li S.R. (2007) .Uptake of toxic heavy metals by rice (Oryza sativa L.) cultivated in the agricultural soils near Zhengzhou City, People's Republic of China, *Bulletin of Environmental*

Loska, K.; Wiechul A, D.; Korus, I. (2004). Metal contamination of farming soils affected by industry. *Environ. Int., 30,* 159–165.

Lushenko MA (2010). A risk assessment for ingestion of toxic chemicals in fish from Imperial beach, California: San Diego State University.

Ming-Ho, Y. (2005). Environmental Toxicology: Biological and Health Effects of Pollutants, Chap.12, CRC Press LLC, ISBN 1-56670-670-2, 2nd Edition, BocaRaton, USA.

Morley A, Turner D. (1999). The contribution of exogenous and endogenous mutagens to in-vivo mutations. *Mutation Research* 428:11-15.

Mustapha O.M and Lawal O.S. (2014). Comparative Study of Heavy Metal Pollution of Sediments in Odo-Owa and Yemoji Streams, Ijebu-Ode Local Government Area, Sw Nigeria. IOSR *Journal of Applied Chemistry* (IOSR- JAC): Vol. 7, Issue 12 Ver. II., PP 17-23.

Ogunkunle, C. O., & Fatoba, P. O. (2013). Pollution loads and the ecological risk assessment of soil heavy metals around a mega cement factory in Southwest Nigeria. *Polish Journal of Environmental Studies*, 22, 487–493.

Ohlendorf H, Covington S, Byron E, Arenal C (2008) Final Guide Approach for Conducting Site-specific Assessments of Selenium Bioaccumulation in Aquatic Systems. Prepared by North American Metals Council Washington, pp. 1-118.

Ouyang Y, Higman J, Thompson J, Toole OT, Campbell D (2002). Characterization and spatial distribution of heavy metals in sediment from Cedar and Ortega *Rivers sub-basin. J. Contam. Hydrol*. 54:19-35.

Özkan E.Y.(2012). A New Assessment of Heavy Metal Contaminations in an Eutrophicated Bay (Inner Izmir Bay, Turkey). *Turkish Journal of Fisheries and Aquatic Sciences 12: 135-147.*

Pekey, H. 2006. The distribution and sources of heavy me t al s i n Gzmit Bay surface sediments affected by a polluted stream. Marine Pollution Bulletin, 52: 11971208.

Rahman, S.H.; Khanam, D.; Adyel, T.M.; Islam, M.S.; Ahsan, M.A.; Akbor, M.A. (2012**)**. Assessment of heavy metal contamination of agricultural soil around Dhaka Export

Processing Zone (DEPZ), Bangladesh: Implication of seasonal variation and indices. *Appl. Sci.*, *2*, 584–601.

Resaee A, Derayat J, Mortazavi SB, Yamini Y, Jafarzadeh MT (2005) Removal of Mercury from chlor-alkali industry wastewater using Acetobacter xylinum cellulose. *American Journal of Environmental Sciences* 1(2): 102-105.

Robert G, Mari G. (2003). Human Health Effects of Metals, US Environmental Protection Agency Risk Assessment Forum, Washington, DC.

Shi P., Xiao J, Wang Y. and Chen L. (2014). Assessment of Ecological and Human Health Risks of Heavy Metal Contamination in Agriculture Soils Disturbed by Pipeline Construction. *Int. J. Environ. Res. Public Health*,*11*, 2504-2520.

Simone Morais, Fernando Garcia e Costa and Maria de Lourdes Pereira (2012). Heavy Metals and Human Health, Environmental Health - Emerging Issues and Practice, Prof. Jacques Oosthuizen (Ed.), ISBN: 978-953-307-854-0, In Tech, Available from: http://www.intechopen.com/books/environmental- health-emerging-q issuesand- practice/heavy-metals-and-human-health.

Sridhara C. N., Kamala C.T. and Raj D.S.S.(2008). Ecotoxicol. and Environ. *Safe*., 69(3): 513-524.

Stezar I.C., Modoi O.C., Török Z., Ajtai N., Crişan A.D., Coşara G.V., Senzaconi F., Ozunu A., (2011), Preliminary investigation and risk assessment of contamination on an industrial site in maramures county, *Environmental Engineering and Management Journal*, **10**, 65-73.

Strachan S (2010). Heavy metal. Curr. Anaesth. Crit. Care 2:44-48.

Swartjes A., Rutgers M., Lijzen J.P.A., Janssen P.J.C.M., Otte P.F., Wintersen A., Brand E., Posthuma L., (2012), State of the art of contaminated site management in The Netherlands: Policy framework and risk assessment tools, *The Science of the Total Environment*, 15, 427-428.

Syers, J. K, Gochfeld, M.. (2000) Environmental cadmium in the food chain: sources, pathways, and risks (M). Brussels: SCOPE Workshop

Tang Q, Liu G, Zhou C, Zhang H, Sun R (2013) Distribution of environmentally sensitive elements in residential soils near a coalfired power plant: potential risks to ecology and childrens health. *Chemosphere* 93: 2473-2479.

Udo P. J. and Arazu V. N, (2011). Biochemical compostion of three exotic fish delicacies Scomber scombrus (Linnaeus, 1758), rachuru Strachurus (Linneaus, 1758) and Sardina pilchard (Walbaum) frozen and imported into Nigeria. *Pakistan J. Nutri.*, 10(12), 1158-1162.

Ukoha P. O., Ekere N. R., Udeogu U. V. and Agbazue V. E. (2014). Potential Health Risk Assessment of Heavy Metals [Cd, Cu and Fe] Concentrations in some Imported Frozen Fish Species Consumed in Nigeria. Int. J. Chem. Sci.: 12(2), 366-374.

USEPA (2012). Waste and cleanup risk assessment. http://www2.epa.gov/risk/waste- and-cleanup-risk-assessment.

Wang, X.,Sato T., Xing B. and Tao S. (2005). Health risks of heavy metals to the general public in Tianjin,China via consumption of vegetables and fish. *Total Environ.*, 350: 28-37.

Wei B. and Yang L. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal* 94 (2010) 99 –107.

Wei, B., Jiang, F., Li, X. and Mu, S. (2009). Spatial distribution and contamination assessment of heavy metals in urban road dusts from Urumqi, NW China. *Microchemical Journal*, 93:147–152.

Yaylali-Abanuz, G. Heavy metal contamination of surface soil around Gebze industrial area, Turkey. *Microchemical Journal*, *99*, 82–92.

Zhang, F.; Yan, X.-D.; Zeng, C.; Zhang, M.; Shrestha, S.; Devkota, L.P.; Yao, T.-D. (2012**)**. Influence of traffic activity on heavy metal concentrations of roadside farmland soil in mountainous Areas. *Int. J. Environ. Res. Public Health*, *9*, 1715–1731.