Environmental and Socio-Economic Impacts of Lead and Zinc Ores Mining in Shaiagu Community of Ebonyi State, Nigeria

Arthur Essaghah. PhD
Department of Urban and Regional Planning
Enugu state University of Science & Technology
(ESUT), Enugu

Chidi Ogbonna. Msc
Lecturer
Department of Geography and Meteorology
Abia State University, UTURU

Micheal. O. Alabi. PhD
Department of Geography and Planning
Kogi State University, Anyigba
Nigeria

Abstract

The exponential rise in the number of small-scale mining activities in Nigeria in recent times has been reported with widespread surface land despoliation and water resources degradation. Against this background, the paper investigated environmental and socio-economic effects of Lead and Zinc Ores mining in Ishaiagu Community in Ivo Local Government Area of Ebonyi State Nigeria. Results obtained from physico-chemical analysis of collected soil and water samples, as well as, related in-situ air parameter measurements all revealed serious environmental pollution and degradation, threatening farming activities in the area. As a consequence the paper recommends that Governments at all levels should enforce all related environmental legislations as a mater of urgency in mining areas if another "Niger Delta Debacle" is to be avoided in various mining communities of the country. Until that happens, farmers and agricultural productivity will remain at the mercy of artisanal and small-scale mining operators and activities in many rural communities of Ebonyi State, and indeed mining areas in Nigeria

Introduction

Increasing realization of the potentials of the solid minerals mining sector in recent tires has made Federal Government of Nigeria to undertake a number of reforms in the sector in order to make it earn more non-oil foreign revenue for the country. Mining industries are now viewed as key drivers of economic growth and the development process (Bradshaw, 2005), and as lead sectors that drive economic expansion which can lead to higher levels of social and economic well being (Bridge, 2008).

Similarly high mineral prices and demand have stimulated an investment surge in mineral exploration and production particularly in developing countries (Okeke, 2008; Mahtani, 2008 and Twerefon, 2009). This situation has led to graving competition between nations to capture investments and consequently, mineral policies legal frameworks and institutions are being reformed in the extractive sector in order to optimize the contribution of mining to the national economy (Murtala 2011:3).

In this regard countries like Madagascar, Ghana, Tanzania, Peru, Agentina and Chile have made remarkable successes (see Girones et al. 2009. Within the last 10 years Nigeria has undertaken giant strides in reforming the solid mineral mining sector, in order to catch up with the rest developing countries. The 1999 and 2007 Mining Acts and the ensuing guidelines made the *Mining Cadastre* the *focus* and *locus* of guaranting a secure mineral rights system in Nigeria. The current state of modernizing the cadastre system from a mining register to a mining cadastre allows for the acquisition of variety of licencing scales that range from a few meters in the case of quarry or small-scale mining to hundreds of square kilometers for exploration and eventual mining (see Ozah et al 2010).

These reforms have drastically increased the number of government-based institutions, agencies and private sector (both foreign and national) investing in the mining sector. It is perhaps in the small scale mining category that interests and activities have grown exponentially. Between May and October 2009, the number of registered artisanal and small scale miners increased from 116 to 234: this figure represents just 5% of miners because it is generally believed that over 95% of artisanal and small scale miners operate illegally (see Lawal, 2002, Murtala, 2011).

On the other hand there are an estimated 180 mining titles and 1003 registered quarry sites spread across the Nigeria as at 2009 (Murtala, 2011). Although small and medium enterprises (SMEs) have been generally regarded as engine of economic growth which artisanal and small mining (ASM) operators represent, a closer scrutiny of their operations indicates they lack necessary capacity to initiate environmental protection measures (e.g. EIA) or even social development projects programmes. In such instances the environmental and social costs of small scale mining (SSM) production are borne by the host communities rather than the SSM cooperatives and associations (see Lawal 2002, Okeke, 2008, Murtala 2011, Ofordile 2003, Eassaghah, Ogbonna and Ugwanyi, 2006).

Although the Federal Government of Nigeria in realization of the potential danger activities of SSM pose to local mining communities has obtained a World Bank loan to organize and stream line their activities, there is need for empirical studies or researches that qualify the severity of environmental problems resulting from their operations. Such studies would serve to reveal the scale of the problems, indicate likely initiatives required to arrest ensuing potential and associated environmental and social conflicts, and provide rational basis for informed intervention policies by government. It is the intention of this paper to examine the environmental and social conflicts of lead and Zinc Ores Mining in Ishiagu Community in Ebonyi State of Nigeria.

The rest of the paper is structured into four parts. Section 2 describes the geographical and geological formation of the study area while the materials and methods adopted for the study are presented in section 3. Research results and discussion of findings are discussed in section 4 and the paper is concluded with recommendations and policy implications in section 5.

Study Area

Mining lease No 17439 covers a land area of about 9.22 hectares (BESL, 2004). It is situated in Ihietutu-Ishiagu in Ivo LGA of Ebonyi State.

It is located approximately in 5°60'N and $7^0$35'E. The area experiences the wet and dry seasons climate regimes. The rainy season is experienced between April to October while the dry season becomes evident from October to March. Maximum temperature of 32^0C is experienced in March with a minimum of 24^0C in July. Population of the area is estimated to be 17,250 people by 2006 (NPC Ebonyi State Office, 20011) .Socio-economically the people of Ishiagu are mainly farmers. The crops cultivated include yams, cassava and rice. Cassava and yam are commercially produced and therefore form the economic base of the area.

In the absence of adequate portable water supply majority of residents depends on surface water streams namely Onuafia, Ihekoyi and Akpaudo, abandoned Zinc and lead Ores mining pits, and Ugwuadu spring for agricultural and domestic uses respectively.Geologically, the Ishaiagu Lead – Zinc deposits form part of the Abakaliki Lead – Zinc field (BESL. 2004). This field occurs within a substantial part of the largest cretaceous sedimentary basis in Nigeria known as the Benue trough. The Ishiagu mineral belt is part of the tectonic – mineralization zone forming the lower Benue field.

The mineral assemblage and associations in the area comprise both primary and secondary mineralization(Offordile 2001). The primary metalliferons deposits in the area include Galena, Sphalerite, Chaleopyrite, Marcasite Cerrurite and Pyromorphite while the gangue minerals associated with the metallic ores include siderite, calcite, fluorite, barite and quartz. Successive mining activities by various companies have depleted this reserve over the years. The pit plan is to developed to a depth of 50m per pit and to use the beneficiated waste to progressive backfill the excavated area which will also be top soiled and replanted with grasses and shrubs to restore and improve stability.

However after 8-10 years of mining activities in the area an estimated 6-7 excavates were abandoned and 3-4 mining pits with average depth of 40m and surface area of between 900-1200m^2 .each existing in the area without any sign of being remedied.

Materials and Methods

A number of methods were adopted for the study in order to examine the different environmental components of the area namely air, water and soil quality. The quantitative methods used involve the collection and laboratory analysis of soil and water samples and air quality assessment. The survey and measurement techniques utilized for this study were in accordance with what Built Environmental Service Limited (BESL) (2004), Essaghah, Ogbona and Ugwuanyi (2006) used in the study of environmental impact of lead and zinc mining in the study area as indicated below in sub sections 3.1, 3.2 and 3.3 respectively.

Air Quality

Three sampling stations in Ihietutu, Amata and Ugwuadu farm area were selected based on prevailing mind direction and minimal local influence. Positioning instruments approximately 500m upwind of major roads using a high volume sampler, a train of impinges with bubbler devices and an automatic gas monitor suspended particulate matter (spm), sulphur dioxide (SO_2) nigrogen oxide (No) and hydrogren sulplude (H_2S), and carbon monoxide (Co) were measured respectively employing adequate precautionary measures. All measurements were taken at about 15 meters above ground level and replicated analysis was made. The specific analytical methods employed in this study are outlined in table 1.0

Table 1.0 Summary of Methods used for Measurement of Air Quality

Polluture	Method	References
1. Suspended Particulate Matter (SPM)	Gravimetric (EPA)	WHO, 1988
2. Sulphur Dioxide	Pararosaniline	Laman, 1992
3. Nitrogen Dioxide	Saltzman	Saltzman, 1954, 1994
4. Carbon Monoxide	NDIR	WHO, 1976, 1995
5. Hydrogen Sulphide	Titrimetric	APHA, 1995

Source: Researcher's Field Survey, 2013

Water Quality

The assessment of water quality in the study involved sampling from six sources namely, onuafia stream, ihekoyi stream, ugwuadu spring, akpuado stream abandoned, mining pit 1 and pit 2. The method used in water analysis was that of the Association of Official Analytical Chemists (AOAC) 1994. Acidity test was done by titrating with 0.1 HaoH using phenolphthalein as indicator. The test for lead was done using spectrometric method (Vogel, 12976). Analysis for zinc was by mercury thiocyrate method. Total calcium and magnesium hardness was determined by titrating $0.1NH_2SO_4$. The test for chloride involved Peavson's method of titrating with 0.1 silver nitrate ($AgNO_3$). Nitrate was analyzed using the Brucine colorimeteric method APHA (1975).

Soil Quality

soil samples were collected at depths of 0-15cm and 15-30cm using the mineral veins from farmlands and from mining pit. The sample is then cooled to room temperature and transferred to a 25oml plastic volumetric flask holding 100ml of distilled water. It was made to the mark with distilled water and this became the stock solution for other tests except for nitrogen which was done using Kjeldall's method. Calcium and magnesium were determined by EDTA method as decided by Vogel (1976) and AOAC (1974). Sodium and Potassium were determined by Flare photometric method (Vogel 1976).

Lead analysis was done spetrometrically (Vogel 1976) while zinc was analyzed using mercury thiocynate method (AOAC, 1974). For phosphorus spectrometric method using ammonium molybdate method to quantify the percentage *phosphorous* was used. Nitrogen was determined by Kjedall's method as described by Saltzmann (1984).

Results and Discussion of Findings

Air Quality

It was observed that the concentration of gaseous pollutants were very low, particularly those of hydrogen sulphide and carbon monoxide (Table 2). However, the concentration of SPM was much higher. This could be attributed to the dust haze during period of measurement.

Table 2.0 Concentration of Air Pollutants in the study area

Station No	Location	Pollutants				
		5pm	SO_2	NO	H_2S	CO/CO_2
		Ug/m^3	Ug/m^3	Ug/m^3	Ug/m^3	Ug/m^3
1	Ihietutu	526.0	<25.0	46.9	<0.1	2.0
2	Amata	688.0	<25.0	35.0	<0.1	2.0
3	Ugwuadu	721.08	<25.0	41.5	<0.1	1.8

Source: Researcher's Field Survey, 2013

When these values were compared with Federal Ministry of Environment (FMENV) air quality standards, the following observation are made (Table 3.0). (Table 3). SPM concentrations at all stations were above recommended values. Gaseous pollutants (SO_2 H_2S and CO_2) had concentrations lower that FMENV values. SPM may be chemically inert, but can absorb chemically active materials, it can soil painted surfaces, reduce air visibility and aggravate respiratory and cardiovascular diseases (Manahan, 1978, WHO 1988; Itan 1994. Air pollutants are intimately associated with a number of respiratory diseases, largely in aggravating existing disorders such as emphysema, bronchitis and asthma (Arday fio-schandoof and Asiedu, 2003).

Table 3.0 Comparisons of Measured Air Quality with FMNEV Standards

	Stations			
Pollutants	Ihuefufu	Amata	Ugwuadu	
	1	2	3	FMENV
SPM ug/ms-1	525.6	686.02	722.1	250
$S0_2$ ug/m3	<26.0	<25.5	<25.0	260
NO_2 ug/m3	46.9	34.2	41.0	75
H_2S ug/m3	0.1	0.1	0.1	8
CO_2 ug/m3	2.1	2.1	1.9	1.0

Source: Researcher's Field Survey, Jan. 2013

Water Quality

Physico-chemical analysis of water showed that total solids ranged from 54mgl at station 5 to 1794mg/lmg/L at station 2 (table 4).Suspended solids was also highest as station 2. At all stations the levels of suspended solids was above the WHO standard of 25mg/L (BESL, 2004). For calcium, all other stations expect station 2 (Ihekoyi stream) have concentrations higher than the WHO standards, while stations 2,3, and 6 only fall within the WHO standards for magnesium. Stations 2 and 6 had hard water having total hardness values of 121.1mg/L and 175mg/L respectively. All samples are below the WHO recommended level of 45mg/1 for nitrate.

Lead and zinc were detected at all stations, but their concentrations were below WHO recommended concentration of 0.05mg/1 and 5mg/1 respectively. However, attention is drawn to station 3 (Ugwuadu spring) which is used for drinking. It is not surprising that lead and zinc were present in all samples as there are extensive deposits of these metals in the study area. (BESL, 2004).

Table 4.0 Values of Physcio-Chemical Parameters of Water in the Study Area

S/NO	Parameter mg/1	STATIONS						FMENV	WHO
		1	2	3	4	5	6		
1	Total solids	126	1794	107	79	54	1531		1500
2	Dissolved solid	124	682	37	14.5	17.5	551		150
3	Suspended solids	53	1112	72	63.1	46.2	981		25
4	Calcium	72	200	625	550	850	300		200
5	Magnesium	501	75	126	226	255	125		150
6	Total hardness	200	225	20	15	10	135		100
7	Calcium hardness (as $CaCO_3$)	21	175	15	201	6.5	121.1		15
8	Magnesium	5	81	5.5	5.1	4	16		25
9	Acidity	15.1	25.2	15.3	10.2	10.1	30.5		25
10	Chloride	25	25.1	50	50	50	25.2		250
11	Lead	0.026	0.048	0.016	0.027	0.02	0.045		0.05
12	Zinc	1.23	3.05	1.35	1.73	1.81	3.52		5
13	Nitrates	0.17	0.06	0.20	0.06	0.05	0.12		45

Source: Researcher's Field Survey, March 2013

Note: (1) Onuafia stream (2) Ihekoyi stream (3) Ugwu-ado spring (4) Pit 1, Pit 11 (6) Akpuado stream

Soil Quality

Table 5 presents the results of soils analysis in the study area.The results shows that samples A and B (farmlands) contain higher values of phosphorous, sodium, potassium and nitrogen. Consequently, they are more fertile than other samples through significant proportion of these nutrients are leached for below where roots of crops can use then. Samples C and D (Along vein) and E and F (Pit) are, having higher concentrations of calcium and magnesium and possibly silica

Table 5.0 Mean Values of Soil Quality Parameters in the Study Area

	STATION						
S/NO		**A**	**B**	**C**	**D**	**E**	**F**
1	Calcium (CaO)	2.91	3.40	3.45	3.88	1.83	1.90
2	Magnesium oxide (MgO)	0.84	0.43	0.83	1.60	0.444	0.46
3	Sodium oxide (NaO)	1.86	1.58	0.69	0.78	0.71	0.58
4	Potassium oxide (K_2O)	2.13	2.50	1.23	1.1.1	0.81	0.80
5	Phosphorus (P_2O_4) Oxide	2.63	2.40	0.46	0.39	0.28	0.17
6	Nitrogen	0.56	0.60	0.11	0.17	0.12	0.15
7	Lead Oxide (PbO)	0.17	0.19	0.17	0.16	0.21	0.20
8	Zinc Oxide (ZnO)	0.80	1.0	1.1	1.08	1.33	1.60

Source: Researcher's Field Survey, Jan. 2013

Note: (a) Farmland 0-15cm (b) Farmland 15-30cm (c) Along rein 0-15cm (d) Along Vein 15-30cm (e) Pit 0-15cm (f) Pit 15-30cm

The presence of lead in particular and zinc can lead to the leaching of soil nutrients (Derome and Lindross 1991) thereby reducing soil fertility and natural vegetation cover (Vangrosveld et al 1991).

Loss of natural vegetation posses a risk for the surrounding area because the absence of vegetation facilitates lateral wind erosion of metal contaminated particles, and may enhance the volume of water percolating through the soil and eventually reaching and contaminating the underlying ground water (Vangronsveld et al 1991; Vangronsveld et al 1995 b). These consequences are undesirable in a fragile, rural, agrarian settlements sustained in large part by agriculture, and where amenities and services such as clean water and health care are grossly inadequate.

This study was undertaken largely to examine the environmental impact of solid mining activities in Ishiagu, a community known for large deposits of lead and zinc ores and has potential of becoming an industrial area in Ebonyi State of Nigeria. One way of ensuring continued exploitation of valuable minerals and harness their positive contributions for sustainable economic and physical transformation of the local communities is to protect existing environmental systems and resources that support the agricultural pursuits and livelihood of the people (Essaghah 2010a; Essaghah and Alabi 2013)

The collection and laboratory analyses of soil and water samples in addition to the measurement of air pollution parameters have all revealed increased soil infertility, pollution of surface water streams and spring used for agricultural and domestic purposes, as well as, rising noise and suspended air particulate levels across the Ishiagu communities. The presence of large excavated pits used for zinc and leads ores exploration/mining (without any form of backfilling as earlier indicated in Environmental Management Plans (EMP) by the various minning operators and its attendant land despoliation and degradation) has forced farmers to source farmlands at far distances from their communities of domicile.

Further more the pollution of Onuafia, Ihekoyi and Akpaudo streams and, in particular that of Ugwuado spring used for drinking purpose by the agrarian settlements (in an environment where amenities and services such as clean water and health care are grossly in adequate is to say the least undesirable. (Essaghah, Ogbona and Ugwuanyi 2006) With the current levels of Suspended Particulate Matter (SPM) in all locations well above Federal Ministry of Environment and World Health Organization (WHO) standards (during the dry season), there is no doubt that the health status of these agrarian communities have become worse for it. Obviously policy has a role to play in reversing these negative socio-economic and healthcare indications.

Recommendations and Policy Implications

The Federal Government should adopt a deliberate policy of direct intervention in the provision of necessary social amenities in industrial areas to complement the efforts of industrial operators if its current emphasis on industrialization and employment creation is to yield desirable results. This will go along way in complementing the various residual mitigation measures usually adopted by mining companies in their areas of operation (Essaghah and Ugwuayi, 2006). In this connection Environmental Regulatory Agencies should stipulate specific mitigation measures that industrial and mining companies must implement in their host communities before granting approval permits.

Rather than leave such decisions to individual companies, regulatory agencies should embark on the development of data base on the problems resulting from industrial operations in the implementation of mitigation measures by investors in these areas. With respect to the Ishiagu community, the Ebonyi State Government through the Ministries of Agriculture, Environment and Water resources should provide direct support services to the people in the area of fertilizer distribution and other farm implements, rural water supply projects including distribution of subsidized water treatment chemicals/kits without delay.

This will help to ameliorate the difficulties rural farmers face in the study area and help arrest the rising incidence of dysentery, typhoid and respiratory related disorders and or diseases. The Ebonyi State Environmental Protection Agency (EBSEPA) should rise up to its statutory responsibilities (in collaboration with the Ebonyi State Ministry of Environment) by embarking on effective monitoring of the activities of mining and quarrying industries in the state to ensure that industrial operators fulfill their social responsibilities to the communities where they operate. They should also,enforce strict implementation of mitigation measures identified and articulated in the respective EIA studies conducted by these industries (Essaghah and Ugwuayi, 2008).

Until this is done industrial concerns in general and mining operators in particular will continue to smile to banks at the expense of the very poor rural farmers land teaming inhabitants who bear the brunt of the damages caused by them and at whose instance the government encourages industrialization. What this implies is that in Ishiagu community, rural farmers in particular and the various governments combined together are subsidizing the current high levels of environmental degradation in the area. This is a development that cost the earth.

References

Association of Official Analytical Chemists (AOAC)(1974). Chemical Analytical Methods AOAC Washington D.C

American Public Health Association (APHA) (1995).Standard Methods for the Examination of Watr and Waste Water, APHA. Washington D.C.

Ardayfio-schardoff .E. and Asizdu, A.B.(2003). The Tropical Environment and Environmental Pollution: The Need for Action. In E.N Adinna, O.B. Ekop and V.I Attah (Eds): Environmental Pollution and Management in the Tropics. SNAAP Press Limited Enugu.

Bastida. E. (2001). A Review of the Concept of Security of Tenure: Issues and Challenges.(Online).Availableat*http//www.dundee.ac.uk/cepmlp/journal/htm/vol7./article7-17htm(2010)*

Bradshaw. M. J. (2005). Population Resources, Development and the Environment, In: Daniels P.E. et al eds. An Introduction to Human Geography: Issues for the 21st Century. 2nd Edition.

Bridge. G. (2008) Economic Geography Natural Resources; In: International Encyclopaedia of Human Geography. (Eds). Kitchen and Thrift. Elsevier

Built Environmental Services Limited (BESL),(2004). Environmental Impact Assessment of Mining of Lead and Zinc Ores in ML 17439 Ishiagu BESL, Enugu.

Derome, J AND Lindroos J (1998).Effects of Heavy Metal Accumulation on Macronutrient Availability and Acidification Parameters in the Vicinity of the Hargavalta Cu-Ni Smelter SW. Finland. *Environmental Pollution 99,225-32.*

Essaghah, A.A.E, Ogbonna .C. and Ugwuanyi B.C.(2006). Lead and Zinc Ores Mining and Environmental Degradation in Ishiagn Community of Ebonyi State. Being a Paper delivered during the Annual General National Conference of Nigerian Environmental Society (NES) held at the Presidential Hotel Enugu between 7th – 9th December 2006.

Essaghah, A.A.E and Ugwu, L.N. (2008). Management Strategy for Monitoring andAuditing Environmental Effects of Brewery Industries in Nigeria: The case of Nigeria Bottling Company Plc. *ESUT Journal of Politics, Ecology and Environment. Vol. 1. No 1.*

Esteves, A. (2008). Mining and Social Development: Refocusing Community Investment and Using Multi-criteria Decision Analysis. Res Policy *33.39-47*

Essaghah, A.A.E. (2010a). The Menace of Flooding in a Rapidly Urbanizing Environments: A case study of Warri Metropolis. Being A paper Delivered on the 4th Edition of Late Professor F.M.A

Ukoli lecture and Award Ceremony/Annual Environmental Workshop of the Nigerian Environmental Society (NES) Delta State Chapter held on 26th November 2010, Warri Delta State.

Essagahah, A.A.E. (2011). A Strategy for Managing Environmental Hazards at the Community Level in Nigeria. Bring a LEAD Paper Presented during the 1st Natural Annual General Meeting(AGM) of the Environmental Management Association of Nigeria (EMAN) held on 7th May 2011 at Sunshine Hotel, Ebeano Estate. New Haven Enugu metropolis, Nigeria.

Essaghah A.A.E. and Alabi, M.O.(2013). Strategy for Promoting Effective Management of Environmental Effects from Brewery Industries at the 9th Mile Corner Industrial District of Enugu State. *International Journal of Energy and Environmental Research: Vol. 3 No. 1.*

Girones. E.O. Pugachersky, A. and Walser, G. (2009). Mineral Rights Cadastre: Promoting Transparent Access to Mineral Resources, Extractive Industries for Development Series ₦ 4 June 2009, Washington DC: The World Bank.

Gyang, J.D.; Nanle, N. Chollom, S.G. (2010). An Overview of Mineral Resources Development in Nigeria: Problems and Prospects. Continental *Journal of Sustainable Development Vol. 1:23-31*

Itam A. (1994). Health Effects of Environmental Pollutants. ST. Louis Press, California.

Kitula, A. (2006). The Environmental and Social-Economic Impacts of mining on Local Livelihoods in Tanzania. *Journal of Cleaner Production*14:405 414.doi:10,1016/j.jelepro.2004.01.012.http://dxoiorg/10.1016/j.jelepro.2004.01.02.

Lahman E. (1992). Determination and Evaluation of Ambient Air Quality: Manual of Ambient Air Quality Control. Germany.

Lawal. M. (2002). Constraints to small-scale Mining in Nigeria: Policies and strategies for Development. Centre for Energy Petroleum Minerals Law and Policy. Annual Review – The Dundee Year book of International National Resources and Energy Law and Policy.

Mahtani. D. (2008). The New Scramble for Africa's Resources. Financial Times Special Report, 28 January: 1-6.

Murtata. C. (2011). An Extensive Analysis of Mining in Nigeria Using a GLS. *Canadian Center of Science and Education Vol. 3 No 1:3-12* (Online). Available at, http://www.ccsenet.orgjgg.doi:105539/jggN3nlp3.

Ofodile, M.E. (2001). Environmental Issues in Solid Minerals Development. Paper presented to the 31st Annual Conference of the Nigerian Institute of Estate Surveyors and Valuers 20-25 March, 2001.

Okeke, C.N. (2008). Geology and Mineral Resources: Blessing or Curse? *The International Lawyer, Vol. 42 No. 1, 193-210.*

Saltzmann, J.E. (1984). Colorimetric Micro Examination of Nitrogen Dioxide in the Atmosphere. Anachem 26:1984.

Vangronsveld, J. Van Assche, F. and Clijesters, H. (1991). Reclamation of a 'Desert like' site in North East of Belgium: Evolution of the Metal Pollution and Experiments In-Situ. In J.G. Farmer (Eds) Proc. International Conference on Heavy Metals in the Environment CEP Consultants; Edinburgh UK.

Vangronsveld J., Sterakx, J., Van Assche, F., and Clijsters H. (1995a). "Reclamation of a Bare Industrial Area Contaminated by Non-Ferrous Metals: In Situ Metal Immobilization and Revegetation" Environmental Pollution 87 51-59.

Vogel, .C. (1976). Inorganic Quantitative Analysis. Longman Publishing Limited, London.

W.H.O. (9976). Selected Methods of Measuring Air Pollutants. World Health Organization. Offset Publications No 24E.

W.H.O. (1988). Assessment of Urban Air Quality. World Health Organization, GEM/AIR,Geneva.