The Relationship between Soil Nutrients Availability and Allotment Garden Practices in Scotland and Poland

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1 Information Concerns STSM

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2 Abstract

Expanding production is one strategy for increasing access to key foodstuffs in urban areas. This result in the demand for allotment plots in urban cities in order to grow their own food. However, there is concern about soil quality driven by various anthropogenic disturbances obstructs allotment garden soil nutrients. Allotment garden practices can improve or have environmental impacts that affect a wide range of ecosystem services, including soil nutrients. Understanding the contribution of various allotment garden practices to the range of ecosystem services would help inform choices about the most beneficial allotment garden practices. The study investigated the relationship between soil nutrients, contaminants availability and allotment garden practice in urban allotment gardens in Poland and Scotland. Soil samples and vegetables sample were collected from twelve allotment gardens in Poland and Scotland in order to investigate the quality of urban allotment soils used in growing vegetables. The pH for samples were analysed, GPS readings and photographs were also taken. Forty soil samples and vegetable samples from the Poland allotment gardens were dried, and later sent to home institute, University of the West of Scotland (UWS) and are currently being analysed for soil nutrients and soil contaminants using Palintest and ICP-MS.

3 Introduction

Allotment gardens are a major component of the cities in both developed and developing world countries and the manner in which allotment owner manage these spaces has a substantial impact on the provision of urban biodiversity. Allotment gardens (AG) originated in Europe during in 18^{th} century when plots of land were made available to poor labourers for the production of vegetables and fruits. Allotment gardens are increasingly expanding and meeting the needs of people wanting to grow their own food in European cities (e.g Scotland, Poland. Urban allotment garden have been adopted for so many reasons in Europe, and serve a variety of purposes for diverse populations. It is adopted because it can provide fresh, high quality vegetables crops; for others, it is the exercise, fresh air, and contact with nature; and for some category, it is the savings on the food costs.

In the United Kingdom there are estimated to be over 300,000 allotment gardens (Pless-Mulloli T, 2004) and fruits and vegetables are often grown in allotment gardens, and some of these allotment gardens have a linked to former industrial activities, coal burning , motor vehicle emissions, waste incineration and dumping (Alloway, 2004).

Supplementing soil with essential minerals, nutrients in urban allotment garden is on the increase in a bid to enhance soil productivity and crop yield(Akinride, 2006). Although trace elements and potentially toxic elements occur naturally in urban allotment garden (Alloway, 1990), elevated levels of Lead (Pb) and Zinc (Zn), Arsenic (As), Copper (Cu), Cadmium (Cd) have been reported in urban allotment gardens (Alloway, 2004). Their sources are suspected to be anthropogenic, such as the application of micronutrient fertilizer, animal manure, sewage sludge and pesticides (Alloway, 2004).

The use of fertilizers, organic manure and other soil nutrients replenishing additives, in order to improve crop yield especially in nutrient depleted soils is on the increase. Too much of fertilizers, manure or sewage sludge can be problematic, while too little means nutrients are not replenished (Akinride, 2006). Studies revealed that PTEs are slowly accumulating in soils with depleting trace minerals receiving soil treatments of fertilizer, manure, etc.(Chang A.C, 2000). An estimated over 75% of garden allotment soils in the United Kingdom were reported to be contaminated with potentially toxic elements .This, however, depends on the physicochemical properties of the urban allotment garden, soil ecosystems, and their impact on physical factors. Excess concentration levels of PTEs have caused the disruption of natural terrestrial ecosystems(Wei et al., 2007).

One of the greatest challenges facing the growing human population is meeting rising demand for food without undermining the soils on which food production depends. Soil is a vital resource which performs key environmental, economic, and social functions. It is non-renewable within human time-scale. Soil resources are under increasing pressure and its quality is decreasing. Long- term and extensive use of soil for gardening with frequent application of agro-chemicals is the one of the major causes of potentially toxic elements (PTEs), such as copper (Cu), Zinc (Zn), Nickel (Ni) and Cadmium (Cd) accumulation in soil.

Human activities and bad gardening practices have changed the character and quality of our soils over time. Good allotment garden practices are therefore essential to maintain and improve soil quality. Soil quality is at risk from a number of threats driven by a range of man-made and natural pressures including organic matter decline, contamination and waste to land contamination. Therefore, there is need to generate field and laboratory information on the nutrients/ elements concentration levels, and soil fluxes of PTEs in urban allotment garden soils.

The aim of the STSM was to investigate the relationship between soil nutrients, contaminants availability and allotment garden practice in urban allotments in Poland and Scotland using Palintest and ICP-MS to generate lab data to compare to questionnaire reports on allotment gardens to ascertain if the activities of the gardeners improve soil nutrients or introduce contaminants to the soil. This will help to understand good gardening practices and bad gardening practices in the urban allotment gardens.

4 Study Areas

Poznan is one of the biggest industrial centres of Poland, where important representatives of food -industry, electronic, electrical, transport (rail rolling stock, cars) metallurgical and chemical producers are located. Poznan environs as well as the whole Wielkopolska region are the areas of intense agricultural production of wheat, rye, potatoes, white beets, cole, vegetables and fruits, being the base for food-industry. Allotments, as a part of urban tradition have been present in the Polish landscape for over one hundred year(Pawlikkowska-Piechota, 2011). There are 83 allotment gardens in Poznan. The AG covers a large part of the city of Poznan with 26153ha. The allotment gardens in Poznan are always big in size e.g Mnikowo is 25, 000 by 23,000 square meter (sqm) with 517 plots, and each plot was 400sqm by 400sqm in size. Euro 2012 allotment garden had 165 plots, Polish army allotment garden had 633 plots, Energetyki allotment garden had 133 plots and the area of the garden was 66265m.

Konin is another interesting visited for sample in Poland. Konin is a city in central Poland and located within the Greater Poland Voivodeship. The allotment visited in Konin was former mining area in some years back but now use for allotment garden.

Greenock is a small town of 44,248 people; the former activities in the town are shipbuilding and shipping. Ayr is small town of 46,050 people, the town was full with manufacturing textiles such as carpets and lining until the factories were closed down in 1970. It is an interesting area to study if there is still any effect of these manufacturing industries on the allotment gardens.

5 Methodology

The researcher visited Poznan from 8th September to 8th October 2014. 10 allotment gardens were visited with the assistance of Dr Lidia Ponizy. Two allotment gardens were visited in Scotland. Soil sampling, vegetables collection and questionnaire were undertaken simultaneously. The soil samples were used to measure a range of soil properties, including soil organic matter, nitrogen, and PTEs. See figure 5.1, 5.2 and 5.3 for the locations of some of the allotment gardens. Each allotment owner participants was visited at allotment garden, a GPS location was recorded at the participant's allotment garden, and photographs were taken.

Figure 5.1 Location of cities with investigated allotment gardens (source: Google Earth)

Figure 5.2 Location of cities with investigated allotment gardens (source: Google Earth)

Figure 5.3 Location of cities with investigated allotment gardens (source: Google Earth)

5.1 Vegetable sampling and soil sampling

Ten sampling sites were selected from the allotment gardens in Scotland (Greenock, Ayr) and Poland (Poznan, Konin) see table 5.1 below for the coordinates. The surface layers of the soils studied showed mainly a loamy sandy texture, except Euro 2012 allotment garden soils that are clay sandy. Forty soil samples and vegetable samples were collected in Poznan and Konin. The sampled allotment garden sites were selected based on the knowledge on the expected spread of PTEs contamination on these gardens. The vegetable samples collected for this study included spinach, beetroot, leeks, radish, Parsley, ginger, carrot, pepper, Kolrabi, Celery. All these vegetable are available and collected in Scotland allotment gardens except Kolrabi and celery that are not common in Scotland allotment gardens. At each allotment garden, paired soil (0-20cm deep) and plant samples were collected at the same spot. Five random soil samples on each plot were taken and bulked together as one composite sample.

Table 5.1. Sampling location and coordinates of selected urban allotment gardens in Poland and Scotland

	Coordinates	
Sampling location	Northing	Easting/ Westing
Euro Allotment	$N52^{0}$ 21^{I} 05.6^{II}	$E016^{0}$ 57^{I} 14.6^{II}
Minikovo Allotment	$N52^{0}$ 21^{I} 09.1^{II}	$E016^{0}$ 56^{I} 49.5^{II}
Energetyki Allotment	$N52^{0}$ 25^{I} 04.7^{II}	$E016^{0}$ 57^{I} 08.0^{II}
Przylesie Allotment	$N52^{0}$ 23^{I} 52.22^{II}	$E016^{0}$ 48^{I} 25.44^{II}
The Second Polish Army	$N52^{0}$ 24^{I} 54.45^{II}	$E016^{0}$ 51^{I} 47.72^{II}
Konin Allotment	$N52^{0}$ 14^{I} 26.4^{II}	$E018^{0}$ 15^{I} 27.1^{I}
Rod Energetyk Allotment	$N52^{0}$ 14^{I} 17.4^{II}	$E018^{0}$ 16^{I} 03.3^{II}
Hutnik Allotment	$N52^{0}$ 14^{I} 05.2^{II}	$E018^{0}$ 17^{I} 23.7^{II}
Wellington Street Allotment	$N55^{0}$ $56^{1}.670^{11}$	$W4^{0}$ $46^{1}1.6^{11}$
Ayr Allotment garden	$N55^{0}$ $27^{1}.29^{11}$	$W4^{0}$ $37^{1}44^{11}$

5.2 Sample preparation and analysis

The soil samples, collected in allotment gardens were prepared according to the ISO 11464 standard. Samples were air-dried at room temperature for 2 weeks and crushed to pass through a 2-mm stainless steel sieve.

The vegetables samples were prepared as a careful consumer would prepare them to eat, with the elimination of the inedible parts and meticulous cleaning in three successive washings of tap water. All precautions were taken to avoid possible contamination. All samples were then cut into small pieces to obtain a representative sample, packed in a polypropylene sachet, kept cool, and transmitted as soon as possible to a location where the vegetables were dried in the oven at 40^{0}C for few hours. A representative part was then digested with concentrated nitric acid using hot block while soil samples was digested with aqua-regia using hot block at 95^{0}C.

The main vegetables produced and selected for study were lettuce, carrot, Parsley, leek, beetroot, celeriac, spinach, tomato, onion, garlic, and Potato. We sampled the vegetables at their consumption stages, taking care to obtain a representative sample (of the vegetable) and sufficient dried matter for the analyses.

The concentrations of PTEs in soils and vegetables were quantified by CRM references. The concentrations of PTEs were measured by inductively coupled plasma atomic emission spectrometry (ICP-OES). The low concentrations of PTEs were determined by inductively couple plasma mass spectrometry (ICP-MS).

5.3 Allotment Questionnaire

A questionnaire use for the study was extracted from the questionnaire prepared by Salzburg group to suit the purpose of this study. 50 questions were prepared by Salzburg group but only 20 questions that are relevant to this study on how environmentally sustainable was the gardening practice were used. Using the questionnaire can help is sharing data and in building data base for COST Action.

A questionnaire was administered in the studies areas between August to October 2014 both in Scotland and Poland to determine gardeners' practices. All allotment holders present at the time of the site visit were asked to complete a questionnaire about plot management. The questionnaire assessed the length of time the plot had been held by the present person; types of OM added; types of fertilizer used; age, gardening practice, the vegetable grown, and gender. A total of 5 gardeners return the questionnaire in Poland while only 7 gardeners return the questionnaire in Scotland.

6 Good garden practices

It is well identified that allotment garden practices change soil conditions and the other living organism in it. However, the relationship between definite practices and soil functions is less clear.

There are best perceptions of how biodiversity can be improved in allotment gardens. Many of these ideas are simple. They can be integrated easily without changing the essential purpose of an allotment garden as a plot of land to be cultivated for the production of vegetables, fruit and flowers.

6.1 Compost: Composts constituted the principal sources of nutrients to crop in most of these allotment gardens. However, some gardeners combine the use of compost and mineral fertilizers. The uses of composts can help in reducing some problems the mineral fertilizer might cause for the soil in long run. The dependence on chemical fertilizers for gardening will have adverse effects on soil properties. Earthworm activity is increased when organic matter such as composted vegetation or farmyard manure is worked into the soil. This helps to keep it open and aerated and also retains moisture near to the roots of crops. Figure 6.1 show an allotment garden in Poznan where all vegetables waste generated on the allotment garden were used for composts.

Figure 6.1 Sample of compost used on Przylesie Allotment garden, Poznan

6.2 Vegetables crops rotation: This basic but vital practice helps not only to prevent the build-up of crop specific, soil based problems, but helps maintain the nutrients balance across the whole area of the garden. Figure 6.2 show a typical allotment garden in Poznan where crops were mixed to create a greater diversity of resources that stimulate soil biodiversity. The plot owner of this plot proved that through crop rotation and intercropping it is possible to encourage a wider variety of organisms, improve nutrients cycling and natural processes of pest and disease control.

Figure 6.2 Vegetable rotations on Przylesie Allotment garden, Poznan.

6.3 Grow a variety of fruit, vegetables and herbs: The owner of the allotment garden also proved that early flowers of gooseberries and currants offer nectar to emerging bees and other insects. Later in the season the flowers of vegetables and herbs will provide that nectar. Since flowers attract different insects and it therefore makes pollination possible.

6.4 Companion plants: In this plot in Przylesie allotment garden, the researcher discovered that certain plants grown together in order to help to reduce attack by pests and diseases. The researcher discovered the reason while onions or leeks grown with carrots in order to help to deter the carrot fly. Then, the reason while French marigolds grown with tomatoes in order to make whitefly infestation less likely. Therefore, Pollination can also be enhanced by planting flowering herbs among the vegetables. The plot visited in Przylesie allotment garden, practice good farming system in all ramifications and this reflected in the quality of the soil and the vegetables grown on the allotment garden.

Figure 6.3 showing the practice of planting flower among the vegetables in Przylesie Allotment garden, Poznan

7 Soil Characterization

7.1 Soil pH

A major soil property affecting the availability of nutrients and potentially toxic elements (PTEs) in soil is pH, a measure of soil acidity or alkalinity.
Soil pH affects the mobility of many pollutants in soil by influencing the rate of their biochemical breakdown and their solubility.
Acidic soils have low pH values and alkaline soils have high pH levels. Soil pH affects the availability of all of the nutrients. For example, copper, iron, manganese, nickel, and zinc are all more available at low pH levels than at high pH levels because metals are bound very tightly to the soil or exist in solid minerals at high pH. Conversely, the 'base' cations (Na+, K^{+}, Ca^{+2}, Mg^{+2}) are bound more weakly to the soil, so can leach out of the surface soil, especially at low pH. A pH range of about 5.5 to perhaps 7.0 seems to be best to promote the availability of plant nutrients.

The pH was determined in a soil using deionised water suspension. 5g of soil sample (air dried) was accurately weighed into a 50ml Sarstedt extraction tube. 12.5ml of deionised water was added to soil. The sample was placed on the shaker and agitated for 10 minutes. Then, the sample was left to stand for 10 minutes. A pH meter was calibrated using buffer solutions of pH 4 and 7 and used to measure the pH of the sample.

7.2 Soil organic matter content

The organic matter content of soils is an important parameter in assessing the quality of a soil. It is formed by the breakdown of plant and animal matter and constitutes a complicated mixture of many different compounds. Soil organic matter content was determined using the method of loss on ignition. The organic matter content is burned off under controlled conditions in a furnace and the organic matter determined gravimetrically.

5g of the soil sample (oven dried) was accurately weighed into a pre-weighed crucible. The weight of the soil (W) and the weight of the soil plus crucible (W1) were recorded. The sample was then removed from the furnace and placed in a desiccator to cool. The sample was re-weighed and the weight was recorded (W2). The soil organic matter (OM) content, expressed as a percentage, was calculated as follows;

$$OM (\%) = \frac{W1-W2}{W} \times 100$$

7.3 Cation exchange capacity (CEC)

CEC is a measure of a soil's capacity to retain and release elements such as K, Ca, Mg, and Na. Soils with high clay and/or organic matter content have high CEC. Sandy, low organic matter soils have low CEC.

Soil testing laboratories do not provide direct measurement of CEC rather an estimate of it based on exchangeable cations. Effective CEC was determined according to the procedure described by Robertson et al, 1999. It involves measurement of exchangeable cations which include both the base cations (K^+, Ca^+, Mg^{2+}, and $Na^{+)}$ and the acid cation (H^+) (Roberston, 1999).

8 Palintest

Soil test results will typically indicate whether a nutrient level is low, medium (moderate) or high (adequate). These levels are known as "nutrient classes" or categories and some labs may break these classes down further to very low, low, medium, high and very high.

8.1 Sample Treatment and Preparation

Samples were oven dried at 40^{0}c for 48hours to eliminate the moisture. The samples were ground to produce particle size that could pass through a 2mm sieve and kept for analysis. After above procedures, preparation of the soil extracts was carried out.

8.2 Extraction Procedures

Extraction procedures used were those recommended in the Palintest soil test book. A plastic extraction tube is filled to the 50 ml mark with distilled water, five extraction tablets added, the tube capped and shaken to dissolve the tablets. Different extraction tablets are available for each analysis to provide suitable extractants. One 2 ml or 10 ml scoop of soil is added to the tube and the mixture shaken for exactly 1 or 2 minutes, depending on the analysis.

8.3 Analysis

The extract is filtered and a suitable aliquot, (1.0 to 10.0 ml) is placed in a photometer tube. Reagent tablets added to the tube are crushed and dissolved. The tube is allowed to stand for a preset time (2 to 10 minutes) to allow the colour or precipitate to develop and the value of the sample is read from the meter in (mg/l). The readings were later converted from Mg/l to mg/kg.

Each soil was then analysed five times for each test parameter and the mean were calculated for each test and for each soil.

9 Results and discussion

Table 9.1 Palintest Result showing the soil nutrients of urban allotment garden in Greenock

Sample ID	Elements (mg/kg)								
	Nitrate	Mg	Al	NH3	Ca	SO4-2	Cl^-	K	PO_4^{3-}
PIB	102.45	66.54	0.19	70.82	2376.43	14.25	472.29	530.61	285.71
P2B	110.2	47.53	0.48	57.03	2566.54	9.51	237.64	571.43	293.88
P3B	67.76	137.83	1.33	22.34	1901.14	14.25	237.64	367.35	293.88
P4B	46.53	42.78	0.67	57.98	2138.78	14.25	237.64	510.2	146.94
P5B	82.45	19.01	0.57	23.29	1901.14	4.75	237.64	489.8	248.98
P6B	63.67	71.29	2.38	34.7	1901.14	19.01	237.64	286.71	363.27
P7B	110.2	61.79	0.1	31.37	2376.43	14.25	237.64	408.16	244.9
P8B	45.71	80.8	1.62	42.78	2376.43	19.01	237.64	408.16	163.27
P9B	75.92	66.54	1.52	54.18	2566.54	14.25	237.64	571.43	204.08
P10B	66.12	123.57	0.29	57.98	2138.78	9.51	237.64	1122.45	257.14
P11B	103.45	109.32	ND	57.5	2138.78	19.01	356.46	714.29	302.04

9.1 ICP-MS Result

Table 9.2 ICP-MS Result showing the level PTEs (mg/kg) in urban allotment garden soils in Greenock

Sample ID	V	Cr	Mn	Pb	Ni	Co	Cu	Zn	As	Cd
P3S3	100.46	26.8	962.8	1250.8	518.2	21.84	180.32	662.2	20.32	5.1
P12S1	117.8	28	870.2	2284	465.4	23.7	264.6	955.8	24.42	1.68
P6S1	65.6	19.99	642	898.2	273.4	14.43	126.2	548.4	15.81	0.93
P7S3	69.1	15.62	992	1089.8	367.8	15.67	123.46	613.6	17.6	1.47
P6S1	92.22	26.96	710.6	1887	415.4	20.32	229	1230.4	20.28	2.6
P7S3	88.26	25.68	666.2	1660.6	643	24.42	169.44	841.4	22.12	1.85
P6S2	126.24	49.64	353.8	1607	721.4	31.62	257.2	963.2	26.64	3.59
P3S2	109.54	24.56	810.8	2338	403.6	20.96	250.6	789.2	20.2	3.16

P8S2	65.6	19.99	642	898.2	273.4	14.43	126.2	548.4	15.81	0.93
P13S1	65.5	19.99	642	898.2	273.4	23.7	126.2	548.4	15.81	0.93
P12S2	107.58	30.32	438.6	1684.8	426.4	19.3	205.6	754.2	20.78	1.45
P13S2	45.42	13.68	514.4	552.2	208.6	10.33	78.68	359.6	10.36	0.62
P12S3	194.98	27.12	612	1705.2	402	22.02	214	804.8	21.64	1.53

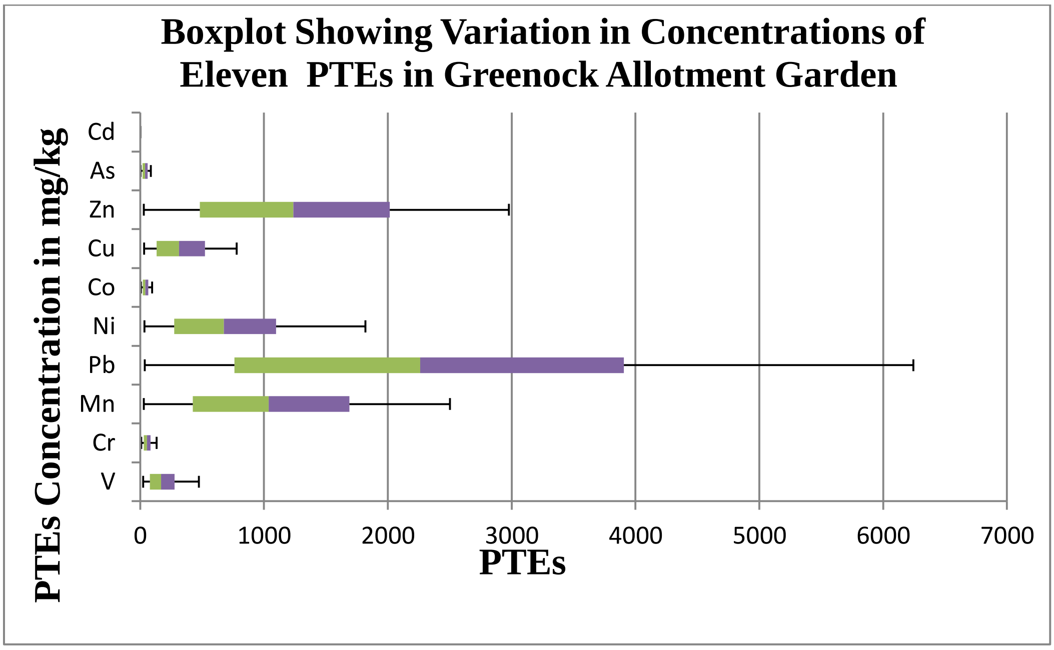

Figure 9.1 Boxplot showing variation in concentrations of eleven PTEs in Greenock allotment garden.

Elemental concentrations across the site are highly variable. This was explained by the soil uses, the past or present anthropogenic activities. Table 2 present the mean values of Lead (Pb), Zinc (Zn) , Manganese (Mn) and Copper (Cu) and Zn concentrations measured in urban allotment garden soil. Elevated levels of Pb are noted throughout the site, variations in the Pb content of the soil are range between (552.2to 2338mg/kg). Also high levels of Zn are noted which range from (359.6 to 1230 mg/kg).

The average concentrations of Cu, Pb and Zn(Alloway, 2008) in soils sampled from allotments garden in Greenock (Scotland) are higher but the results of those PTEs for Poznan allotment gardens are not yet ready. The results showed that the highest concentrations of Pb were measured (2) the Cd concentrations were under the detection limit in most cases. These high values, being strongly interrelated, stipulate intensive gardening use, including organic and mineral fertilization. Another issue that might contribute to potential toxic elements soil contamination is the use of composts made of contaminated vegetation. The widespread use of pesticides, the composition of which was generally based on salts of PTEs, may neither be disregarded.

Table 9.3 ICP-MS Result showing the level PTEs (mg/kg) in urban allotment garden vegetables in Greenock

Sample ID	V	Cr	Mn	Pb	Ni	Co	Cu	Zn	As	Cd
P3S3/Le	0.255	0.88	22.4	1.69	1.323	0.13	3.95	29.8	0.77	0.06
P12s1/Tu	0.405	0.78	5.51	8.01	1.143	0.08	5.09	114.73	0.85	0.13
P13s1/Tu	0.275	0.43	3.54	0.8	0.88	0.06	2.92	26.15	0.76	0.02
P6S1/ Ka	0.775	1.7	227.2	13.69	5.44	0.29	11.59	64.2	1.04	0.21
P7S3/Lk	0.66	1.01	84.68	6.4	3.92	0.21	7.9	293	0.88	0.74
P6S2/Lk	0.623	0.803	12.63	6.5	1.883	0.12	6.68	49.4	0.86	0.05
P3S2/Lk	0.838	1.29	19.32	9.77	2.43	0.14	5.803	92.55	0.81	0.27
P8S2/Lk	0.65	0.91	14.35	6.14	2.27	0.11	5.6	61.5	0.77	0.16
P13S1/Lk	0.465	0.46	13.28	2.25	1.27	0.05	7.77	65.63	0.77	0.11
P13S1/Be	0.283	0.583	6.94	2.39	0.74	0.18	7.71	155.78	0.93	0.22
P12S2/Be	0.235	0.87	13.28	4.25	1.97	0.11	7.78	139.9	0.84	0.31
P13S2/Fe	0.34	1.39	24.16	1.14	3.58	0.1	8.83	78.58	0.72	0.2
P12S3/Sp	0.292	2.24	12.68	3.47	4.96	0.13	4.98	105.6	0.8	0.21

NOTE: Le =Lettuce, Tu= Turnip, Ka= Kale, Lk = Leek, Fe =Fennel, Sp = Spinach, Be= Beetroot,

Concentrations of manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), nickel (Ni),chromium (Cr), vanadium (V), arsenic (A), cobalt (Co) and cadmium (Cd) in different vegetables collected from urban allotment garden are given in the table 9.3. Concentrations in these samples are varied quietly such as Mn (3.54–227.2 mg/kg), Zn (26.15–155 mg/kg), Cu (2.92–

11.59mg/kg) ,Pb (0.8– 13.69 mg/kg), Ni (0.88–5.44 mg/kg), Cr (0.43–2.24 mg/kg), V (0.235–0.838mg/kg), As(0.72 – 1.04mg/kg), Co (0.1–0.29mg/kg) and Cd(0.2–0.74mg/kg)

The obtained results of the present study showed that the concentration of PTEs in one vegetable is much high than other vegetables. Kale maintained highest Mn, Pb and Cu, Ni, Co concentration (227.2, 13.69, 11.59, 5.44, 0.29, 1.04, 1.04 mg/kg).

9.2 Soil Plant transfer factor

An approach to assess the uptake of elements in to plants from soil is to determine the transfer factor (TF). The transfer factor is defined (Cui et al., 2004) (Huang et al., 2006) as shown below:

TF = Cplant / Cpseudo total-soil

Where Cplant is the concentration of an element in the plant material (dry weight basis) and Cpseudo total-soil is the total concentration of the same element in the soil (dry weight basis). In order to apply this approach, the vegetables and soil were sample from the same spot(Kabata-Pendias, 2004). The PTEs content of the site at the specific locations (Fiure3.2) was determined in table 7.2. Crop PTEs concentrations expressed in mg/kg of dry weight were used to study the crop/soil behaviour.

Elevated levels of Pb are noted throughout the site, variations in the Pb content of the soil are range between (552.2to 2338mg/kg). Also high levels of Zn are noted which range from (359.6 to 1230 mg/kg).

Table 9.4 Transfer Values for PTEs uptake in Greenock allotment garden, Scotland

Element	SAM 1	SAM 2	SAM 3	SAM 4	SAM 5	SAM 6	SAM 7	SAM8	SAM9	SAM10
V	0.003	0.003	0.004	0.011	0.007	0.007	0.007	0.006	0.007	0.004
Cr	0.003	0.028	0.022	0.109	0.037	0.031	0.026	0.037	0.023	0.029
Mn	0.023	0.006	0.006	0.229	0.119	0.019	0.055	0.018	0.021	0.011
Fe	0.002	0.001	0.001	0.001	0.004	0.003	0.003	0.004	0.003	0.001
Ni	0.003	0.003	0.003	0.015	0.009	0.003	0.003	0.006	0.005	0.003
Co	0.006	0.003	0.004	0.019	0.103	0.005	0.004	0.005	0.003	0.008
Cu	0.022	0.019	0.023	0.094	0.035	0.039	0.023	0.022	0.062	0.061
Zn	0.045	0.12	0.048	0.105	0.238	0.059	0.096	0.078	0.12	0.284
As	0.038	0.035	0.048	0.059	0.043	0.039	0.031	0.038	0.049	0.059
Cd	0.012	0.077	0.022	0.143	0.285	0.027	0.075	0.051	0.118	0.237
Pb	0.001	0.004	0.001	0.013	0.003	0.004	0.006	0.003	0.003	0.003

NOTE: SAM 1=Lettuce, SAM2 = Turnip, SAM 3 = Turnip, SAM 4= Kale, SAM 5 = Leek, SAM 6= Leek, SAM 7=Fennel, SAM8 = Leek, SAM 9 = Spinach, SAM 10 = Beetroot,

Figure 9.2 Boxplot showing transfer factors for the vegetable grown on Greenock garden

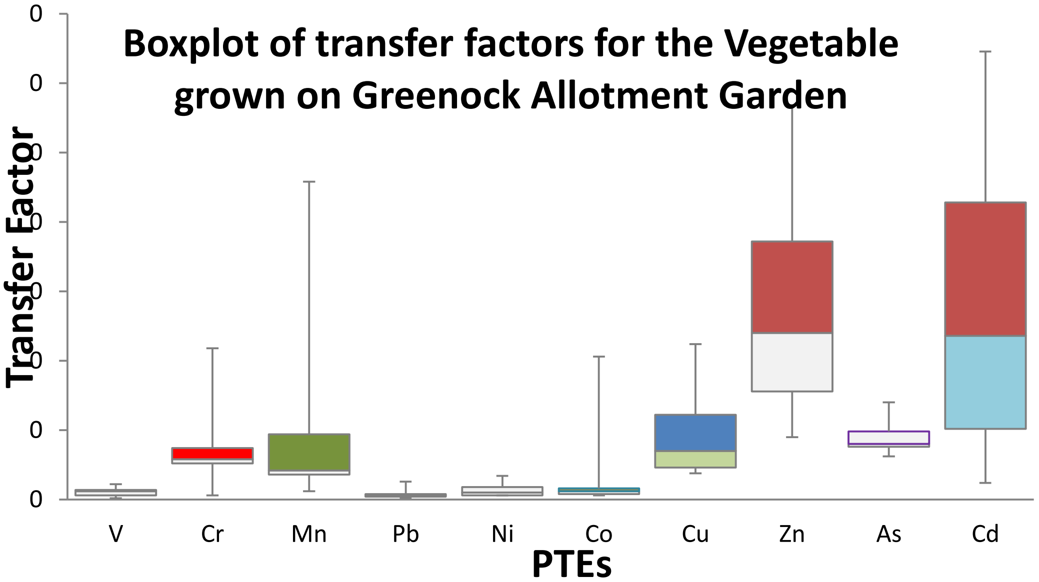

Figure 9.2 Boxplot showing transfer factors for the vegetables grown on Greenock garden

The research shows that the level of PTEs contamination in the soil is relatively high for some elements e.g Pb , Zn, Mn and Cu but the suspected risk to human health based on soil-to-plant transfer ratio is negligible.

Table 9.5 Physiochemical properties of Wellington Allotment Garden, Scotland

PLOT	PH	LOI (%)	Exch Ca	Exch Mg	Exch K	Exch Na	ExcAcidity	CEC (Cmol/kg)
P1B	6.8	18.8	0.53	0.33	0.01	1.39	11.52	13.78
P2B	7.5	17.7	1.47	0.58	0.06	1.23	11.15	14.49
P3B	6.1	21.2	0.37	0.55	0.04	1.85	13.44	16.25
P4B	6.5	16.7	0.51	0.35	0.04	2.24	15.36	18.5
P5B	6.6	16.6	0.41	0.36	0.6	1.76	13.44	16.57
P6B	5.9	18.8	0.38	0.3	0.04	2.46	11.52	14.7
P7B	6.1	21.1	0.5	0.39	0.04	2.68	15.36	18.97
P8B	6.7	19.5	0.55	0.49	0.07	3.11	11.15	15.37
P9B	6.7	19.3	0.58	0.47	0.05	2.35	15.36	18.81
P10B	6.4	22.6	0.7	0.78	0.08	2.73	13.44	17.73

The texture of soils in allotment gardens in Greenock are loamy sand. Most of the soils from Poznan are loamy sand except the soils from Euro 2012 allotment which are sandy. Soils from gardens display a relatively high content of organic matter. The site ranges from weakly acidic to neutral soil (mean 6.1 to 7.5) with low organic matter content while the exchange capacity was within the normal range.

9.3 Relationship between soil characteristics and mobility and availability of PTEs

Soil pH is one of the most important factors in the control of the absorption, mobility and bioavailability of PTEs in the soil solution. A high pH contributes to a decrease of PTE mobility by the formation of precipitates, which increases the number of adsorption sites and decreases the competition of H^+ for adsorption, thereby increasing the PTE stability with humic substance.

The % LOI contributes to the soil CEC and a high value of % LOI results in a high value of CEC, which will have direct impact on the availability of PTEs.

9.4 Allotment Management (Result of the questionnaire)

From the questionnaire, the length of time the 12 allotment holders had managed their plots ranged from 2 to 10 years in Scotland while in Poland it ranged from 3 to 15, with a median duration of 5 and 8years respectively for Scotland and Poland, 25% and 60% of respondents having held their plots for more than 5 years in both countries .Most gardeners, 85% in Scotland and 80% in Poland affirmed that they use self- generated compost on their allotment gardens, while 58% in Scotland and 75% in Poland confirmed that they used both self-generated compost and organic fertilizer. Only few, 29% in Scotland and 20% in Poland of the gardeners uses large chemical fertilizers on their allotment gardens.

29 % in Scotland and 90 % in Poland cultivate soft fruits like strawberries/blackberries and fruits from tree like apple, apricot etc. in their allotment gardens. All the allotment holders cultivate series of vegetables in their allotment gardens while 80% of the respondents in Poland cultivate vegetables in their allotment gardens.

10.0 Conclusions

The concentration of potentially toxic elements (PTEs) (Pb, Zn , Mn and Cu) in topsoil of allotment gardens in Greenock, Scotland is highly spatially varied, but varies with the amount of organic matter, pH and the content of plant-available macro-nutrients, which suggests a relationship between PTEs contamination and the intensity of organic and mineral fertilization. The research shows that the level of PTEs contamination in the soil is relatively high for some elements e.g Pb , Zn, Mn and Cu but the suspected risk to human health based on soil-to-plant transfer ratio is negligible.(Marwa et al., 2012, Hang et al., 2009)

The Poznan data is not yet ready as at the time of writing this report, all the data will be integrated in my final report. The data are not ready because of some circumstances that beyond my control. The one month visit to Adam Mickiewicz University, Poznan (Poland) to share ideas on input and output of materials to the allotment garden soils in order to ascertain whether the input improve the nutrients of the garden or causing contaminants in the allotment gardens was a success with gain and motivation for collaboration for my broader study. It provide future collaboration for wider area of similar interest, Furthermore, additional data will be produced from the on-going chemical analysis at home institute which will be used to justify the result of the questionnaires from the allotment gardens.

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Appendix

Allotment Garden Questionnaire

***01.* Have you improved your garden since you use it?** *(multiple answers possible)*

- o I cultivate the terrain/area (there was no garden before)
- o Amelioration/improvement of the soil, accumulation of humus
- o I plant trees and/ or shrubbery/bushes
- o Cultivation of fruits/vegetables
- o Construction of cabin, terrace tec.
- o I establish areas for wild plants /animals
- o No, it was already perfect
- o Others (please fill in): …………………………………………………..

02. Do you improve the soil conditions in your allotment? If yes, what kind of amelioration? *(multiple answers possible)*

- o yes   o no
- o Turf   quantities used per m^2/year:_____
- o Self-generated compost   quantities used per m^2/year:_____
- o Organic fertilizer / dung   quantities used per m^2/year:_____
- o Chalk   quantities used per m^2/year:_____
- o Phosphate fertilizer   quantities used per m^2/year:_____
- o Nitrogen fertilizer   quantities used per m^2/year:_____
- o Chemical multi-range fertilizer   quantities used per m^2/year:_____
- o Others (please fill in): …………………………………… quantities used per m^2/year:_____.

03. Do you use chemical insecticides / pesticides / herbizides?

- o Regularly   o Sometimes
- o on rare occasions   o Never

04. Do you use biological insecticides / pesticides / herbizides?

o Regularly o Sometimes

o on rare occasions o Never

05. .Which type of garden fruits / vegetables do you cultivate mainly? *(multiple answers possible)*

o Salads

o Herbs

o other vegetables

o Soft fruits: Strawberries/ blackberries / raspberries

o Fruits from trees (such as apple, apricot, cherry, peach, plum)

o Others (please fill in): ……………………………

06. What do you think about an environmentally sustainable garden?

(An environmentally sustainable garden contains e.g. flower meadows, wetlands („tarns“) as habitat or food source for insects and small animals, instead of solely cultivated lawn. No pesticides or synthetic fertilizers are used etc.)

o little – I want to produce vegetables/ fruits in my garden

o little – I like my garden well maintained

o It would agree with me / it would suit me well

o My garden is already environmentally sustainable

o I don’t know

07. How would you describe your garden? *(multiple answers possible)*

o It is well maintained, tidy and proper: no weeds at all

o It is half-decent

o There are some areas, where I don’t care about weeds and let them be

o I don’t care about weeds too much

o My garden has a high amount of different plants

08. Are you anxious to reduce the effort for care in your garden?

- o Yes
- o No

09. Which conceptions/ideas determine your garden design? *(multiple answers possible)*

- o Beauty
- o Production (vegetables/fruits) for subsistence
- o Low-Maintenance
- o A multitude of different plant species
- o Environmentally sustainable design
- o Nice place for recreation and relaxation (not too much work)
- o Ideals from gardening magazines, TV-shows etc.
- o Ideals from the gardens of neighbors/club-members
- o I do not have specific conceptions
- o Others (please fill in):………………………………

10. If you have your allotment garden for more than 10 years: What have you changed in the last 10 years in your garden? *(multiple answers possible)*

- o More lawn
- o Less lawn
- o More vegetable patches
- o Less vegetable patches
- o More flower-beds
- o Less flower beds
- o More space for leisure time (terrace, pergola, barbecue area)
- o Less space for leisure time (terrace, pergola, barbecue area)
- o More possibilities / bigger area for children to play
- o Less possibilities / smaler area for children to play
- o I have reduced the grade of maintenance
- o I have increased the grade of maintenance
- o Nothing
- o Others (please fill in):………………………………

11. What kind of water do you use in the garden and in which extent?

- o groundwater = ……….% of total water consumption
- o rainwater = ……….% of total water consumption
- o public (drinking) water = ……….% of total water consumption
- o river, stream, lake water = ……….% of total water consumption
- o Others……………………….=……….. % of total water consumption

12. Do you think that you behave ecological/sustainable in your allotment?

- o Yes, always
- o Mostly / more often
- o Sometimes
- o hardly/ rather seldom
- o Never
- o I don't know

I. Personal Data

(All your data remains totally anonymous!)

13. What age group are you in?

- o 20 - 30 years
- o 50 - 60 years
- o 30 - 40 years
- o 60 – 70 years
- o 40 - 50 years
- o over 70 years

14. I am:

- o female
- o male

15. What kind of engagement/job do you have at the moment?

- o Unemployed
- o Pupil /Student
- o Part-time employment
- o Parental leave
- o Retiree
- o Full-time employment
- o military- / civilian-service
- o Homemakingr
- o Other
- o prefer not to say

16. **What were the main motivations for choosing an allotment?** (*multiple answers possible)*

O Recreation and recovery

O Space for children to play

O I love gardening / gardening is my hobby

O Silence, place for retreat

O Self-supply with fruits and vegetables

O Compensation for missing balcony / terrace / garden

O to establish ties with others / Community spirit

O Connectivity to nature

O Others (please fill in): ………………………………………………………

17. **How often do you spend your free time in your allotment?**

Please differentiate for summer (season of planting/seeding to harvest) and winter:

Summer		*Winter*
o	Daily	o
o	Several times a week	o
o	Almost each weekend	o
o	A number of times monthly	o
o	More seldom/scarce	o

18. **How many hours do you spend on average <u>at one day</u> at the allotment in the season?**

on working days: ………..hours on weekend: ………..hours

19. **Please estimate the time you spend for the following activities (in percent):** (100%= your total time in the allotment)

……% seeding, planting and plant care: fruits and vegetables

……% seeding, planting and plant care: ornamental plants

……% lawn care (mowing)

……% take care of built-up areas (cabins, footways and terrace)

……% work in association

……% talking to neighbors/ association members

……% relaxing, sunbathing, reading, watching my garden….

……% other *(please fill in)*: ……………………………………………..

100 % total

20. With whom do you mainly use the allotment?

O alone / by myself

O with my husband / partner

O with my family

O with friends