Seasonal Evaluation of Trace Metals in Irrigated Soils at Various Sites in Phuleli Command Area (Sindh), Pakistan

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Abstract: Phuleli Canal (Sindh) Pakistan is the main source of irrigation water for lower Sindh. However, its quality has been deteriorated by the addition of industrial effluents and city wastes discharged directly or indirectly into canal when it passes through Hyderabad city. For monitoring the effect of this canal water on soil quality of the command area, the present study was designed to evaluate the seasonal variability of trace metals including Cu, Fe, Zn and Mn in the cultivated soil area. The soil samples were collected from different seven sites (reduced distance, RD = 304.8 m) RD-0, RD-30, RD-50, RD-70, RD-90, RD-110 and RD-130) in four seasons (summer, autumn, winter, and spring) and analysed for Cu, Fe, Zn and Mn contents. Then, the obtained results were compared with the maximum permissible values of FAO for agriculture/crop production. Results showed that the Zn contents in soil samples was relatively higher than FAO permissible limits during winter in all soil layers and all sites mostly at upper reach sites of Phuleli Command area. While, the Fe content in soil at all depths was found higher during winter, autumn and spring. Whereas, in summer season it was relatively more in upper soil layers near mid to down reach sites and were not within the permissible limits of FAO. Same was true with Cu and Mn which were also not within the permissible limits of FAO for crop production. So, it was inferred that almost of the locations trace elements in soils found higher under Phuleli Canal Command area were mainly produced from various pollution sources *viz,* industrial and municipal liquid effluents.

Keywords: Seasons, Soil, Trace metals, Phuleli Canal.

INTRODUCTION

Trace metals take place naturally in rocks and soils, but increasingly higher amounts of them are being released into the environment by anthropogenic activities. There are environments (or regions) in which anthropogenic loads of trace metals puts ecosystems and their residents at a health risk. Frequent use of metal-rich chemicals, fertilizers, and organic amendments such as sewage sludge and wastewater may cause contamination at a greater level [1]. Trace elements *viz.* Iron, Zn, Cu, Mn, Pb and Co was increased by the irrigation using sewage water as compared to virgin soil [2].

An estimated 25-35 million people in the Indus basin live in areas with brackish groundwater with very low rainfall; hence they rely on surface irrigation water for all their water needs, including washing, bathing, and drinking [3]. In most towns in Pakistan, which have a sewage disposal system, the wastewater is used for irrigation. Recent estimates reveal that about 26% of vegetable production comes from fields irrigated with wastewater [4]. In the cases where wastewater is not used directly, it is disposed off in the most convenient surface water bodies, which often are irrigation canals that often adversely affected by the agriculture field at down reach. Like many other developing countries, the wastewater in Pakistan is being used for irrigation to raise the vegetables and crops in the immediate surroundings of the cities and the towns. However, a better taste is observed in vegetables grown with canal water than sewage irrigated vegetables [5]. The crops grown in the contaminated soils may also accumulate heavy metals in excessive quantities in various food parts [6] which in turn may cause clinical problems in animals and human beings all over the world. Some general toxic effects of the heavy metals are hepatic damaging, anaemia, haemolysis, severe diarrhoea, dizziness, cirrhosis and degeneration of basal ganglia of brain and liver [7].

Like other cities of Pakistan, Hyderabad is also facing a great problem of safe disposal of wastewater. Highly toxic run-off from plastic factories, illegal cattle pens, slaughterhouses and sewage water is directly disposed off either by gravity flow or by means of pumping into Phuleli Canal without any treatment [8] as

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ISSN: 1814-8085 / E-ISSN: 1927-5129/15

it passes through Hyderabad. As a result, Phuleli Canal has put in jeopardy lives of millions of people in Hyderabad, Badin, Tando Muhammad Khan and Matli towns of Sindh province of Pakistan because they use this polluted water for irrigation purpose and drinking [9-11]. This untreated sewage water contains dissolved and suspended solids, inorganic and organic compounds, oils, solvents, greases, thermal discharge, etc. The groundwater is said to be polluted due to leachate of harmful chemicals and is considered unfit for drinking and agricultural use [12]. Also it has been the interest of the public to know whether vegetables, fruits and food crops cultivated in polluted soils are safe for human consumption [13]. The present study is therefore, an attempt to assess the seasonal distribution of trace metal in irrigated soils of Phuleli Canal Command area.

MATERIAL AND METHODS

Soil quality for trace metals were examined for four seasons (summer, autumn, winter and spring) at seven sites (reduced distance, RD = 304.8) RD-0, RD-30, RD-50, RD-70, RD-90, RD-110 and RD-130) of Phuleli Canal Command area. These sites commence from Kotri Barrage (Ghulam Muhammad Barrage) towards RD-30, RD-50, RD-70, RD-90 situated in Hyderabad district, while RD-110, RD130 fall in Tando Muhammad Khan district (Figure **1**). The trace and heavy status

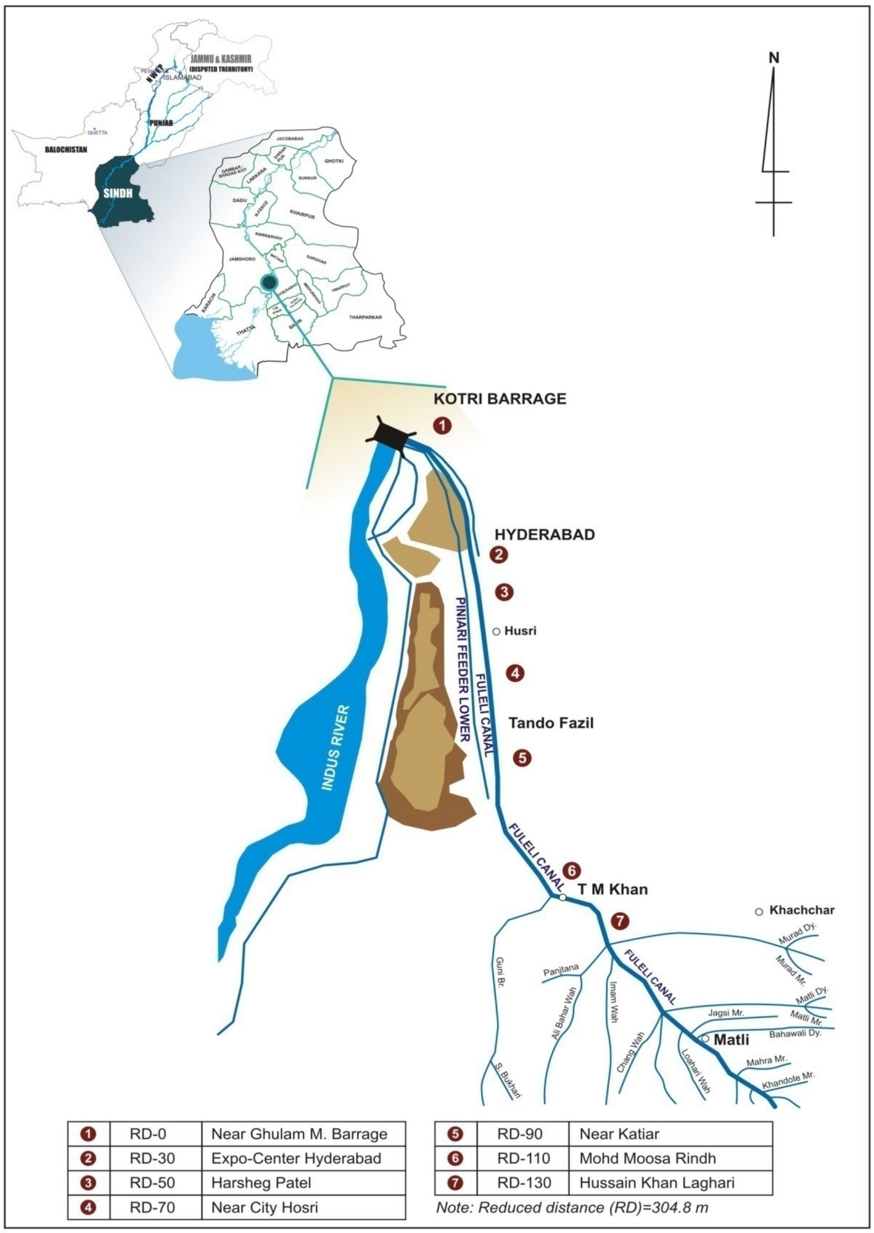

Figure 1: Map showing locations/sites along Phuleli Canal Command area from where soil samples were taken.

was then compared with FAO [14] standards used by [15] for irrigated soil.

Soil Sampling

For determinations of trace metals, composite soil samples were taken at different soil depths (0-20, 20-40 and 40-60 cm) with the help of auger from each site about 100-110 m away from the Phuleli Canal. All the samples were labeled with sample code, date and time of sample collection. The samples were sent to the laboratories of the Department of Land and Water Management, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam and Drainage Reclamation Institute of Pakistan, Tandojam. The soil samples were air dried, ground and passed through 2 mm sieve, mixed thoroughly and stored in clean labeled plastic containers for soil trace metals determinations.

Trace Metals Determinations

Trace metal (Zinc (Zn), Cupper (Cu), Manganese (Mn) and Iron (Fe)) contents in soil samples was determined by digesting the sample in the acid mixture (Conc HNO_3- H_2O- Conc HCl) [16]. Trace metals concentration was determined by atomic absorption spectrophotometer Model (Analytic-Jena-Germany, Model AAS-Vario-6).

Statistical Analysis

The data obtained were subjected to statistical analysis with analysis of variance technique. The LSD (Least Significant Differences) test was used to compare the individual treatment means as per the statistical methods developed [17]. The above statistical analyses were performed using MSTAT-C Computer Software.

RESULTS

Trace elements are necessary chemical elements that are needed in minute quantities for the proper growth, development and physiology of an organism [18]. The trace elements concentrations in the irrigated soils in the Phuleli Canal Command area (Tables **1-3A-B**) are compared with FAO threshold values for Crop production.

Statistical analysis of variance showed that all trace metal contents in soil such as Zn, Fe, Cu and Mn, during various seasons of the year varied significantly in the canal command area of Phulleli Canal. Zn (2.3 ppm) and Fe (7.19 ppm) contents in soil during winter season was relatively higher followed by autumn and were lower in spring and summer. But the Cu (1.71 ppm) and Mn (0.74 ppm) content were found higher in summer and were lower in spring, autumn and winter (Table **1**). Both Cu and Mn contents in all seasons

Table 1: Trace and Heavy Metals Content in Soil at Various Seasons Along Phuleli Canal

Parameters (ppm)	SE	LSD (5%)	Seasons				*FAO (ppm)
			Summer	Autumn	Winter	Spring	
Zn	0.00127	0.0057	1.69 d	2.18 b	2.30 a	1.94 c	2
Fe	0.01195	0.0540	4.88 d	6.32 b	7.19 a	5.58 c	5
Cu	0.00126	0.0058	1.71 a	1.55 c	1.45 d	1.63 b	0.2
Mn	0.00127	0.0057	0.74 a	0.62 c	0.58 d	0.67 b	0.2

In each row, means followed by common letter are not significantly different at 5% probability level.
*Recommended Maximum concentration for irrigation/crop production [14-15].

Table 2: Trace and Heavy Metals Content of Soil at Various Location/Sites Along Phuleli Canal

Parameters (ppm)	SE	LSD (5%)	Locations							*FAO (ppm)
			RD-30 (Regulator)	RD-30	RD-50	RD-70	RD-90	RD-110	RD-130	
Zn	0.00168	0.0058	2.39 a	2.31 b	2.13 c	1.99 d	1.90 e	1.80 f	1.68 g	2
Fe	0.0157	0.055	4.92 g	7.14 a	6.79 b	6.39 c	5.94 d	5.45 e	5.31 f	5
Cu	0.0017	0.0058	1.21 g	1.29 f	1.52 e	1.62 d	1.71 c	1.83 b	1.89 a	0.2
Mn	0.0018	0.0017	0.42 g	0.88 a	0.78 b	0.74 c	0.69 d	0.53 e	0.5 f	0.2

In each row, means followed by common letter are not significantly different at 5% probability level.
*Recommended Maximum concentration for irrigation/crop production [14-15].

Table 3A: Interactive Effect of Seasons x Depths x Locations (Trace Metals) of Soils Along Phuleli Canal

Seasons	Soil Sampling Depths (cm)	Locations	Trace Metals (ppm)			
			Zn	Fe	Cu	Mn
Summer	0-20	RD-0 (Regulator)	2.31 m	4.15z	1.453 u	0.56 w
		RD-30	2.21 qr	6.95 l	1.55 r	1.21 a
		RD-50	2.12 t	6.34 no	1.98 f	0.98 b
		RD70	1.85 wx	5.98 p	2.010 e	0.94 cd
		RD-90	1.84 x	5.46 r	2.120 d	0.88 ef
		RD-110	1.73 z	4.35 z	2.31 b	0.68 p
		RD-130	1.68 z	4.26 z	2.41 a	0.67 pq
	20-40	RD-0(Regulator)	2.27 no	4.22 z	1.26 z	0.45 z
		RD-30	1.98 u	5.88 pq	1.35 yz	0.93 d
		RD-50	1.96 u	5.77 q	1.63 p	0.88 e-g
		RD70	1.77 y	5.27 st	1.77 l	0.87 fg
		RD-90	1.72 z	4.98 uv	1.87 i	0.77 lm
		RD-110	1.58 z	4.80 wxy	1.93 h	0.59 v
		RD-130	1.25 z	4.98 uv	1.96 g	0.58 vw
	40-60	RD-0 (Regulator)	1.66 z	2.87 z	1.18 z	0.43 z
		RD-30	1.58 z	4.96 u-w	1.23 z	0.84 ij
		RD-50	1.38 z	4.68 yz	1.37 xy	0.78 kl
		RD-70	1.33 z	4.38 z	1.48 t	0.73 n
		RD-90	1.16z	4.19 z	1.58 q	0.68 p
		RD-110	1.13 z	4.16 z	1.67 no	0.53 x
		RD-130	1.02 z	3.89 z	1.69 m	0.53 x
Autumn	0-20	RD-0 (Regulator)	2.89 c	6.26 o	1.31 z	0.45 z
		RD-30	2.77 d	8.81 s	1.38 wx	0.97 b
		RD-50	2.74 f	8.35 e	1.76 l	0.89 e
		RD70	2.50 i	7.71 gh	1.88 i	0.87 fg
		RD-90	2.35 l	7.26 jk	1.98 f	0.83 j
		RD-110	2.25 op	6.88 l	2.12 d	0.62 u
		RD-130	2.12 t	6.5 m	2.27 c	0.57 w
	20-40	RD-0 (Regulator)	2.77 d	5.22 st	1.18 z	0.47 z
		RD-30	2.76 de	7.56 hi	1.23 z	0.86 gh
		RD-50	2.32 m	7.27 jk	1.44 u	0.71 o
		RD70	2.27 no	6.95 l	1.58 q	0.65 rs
		RD-90	2.13 t	6.21 o	1.68 mn	0.63 s-u
		RD-110	2.13 t	5.51 r	1.840 j	0.48 yz
		RD-130	1.96 u	5.36 rs	1.87 z	0.47 z
	40-60	RD-0 (Regulator)	1.98 u	4.98 uv	1.10 z	0.38 z
		RD-30	1.85 wx	5.90 pq	1.15 z	0.68 p
		RD-50	1.73z	5.77 q	1.23 z	0.64 st
		RD70	1.67 z	5.24 st	1.27 z	0.56 w
		RD-90	1.62 z	5.21 st	1.37 xy	0.52 x
		RD-110	1.60 z	4.88 v-x	1.44 u	0.40 z
		RD-130	1.43 z	4.76xy	1.49 t	0.37 z

In each column, means followed by common letter are not significantly different at 5% probability level.

Table 3B: Interactive Effect of Seasons x Depths x Locations (Trace and Heavy Metals) of Soils Along Phuleli Canal

Seasons	Soil Sampling Depths (cm)	Locations	race Metals (ppm)			
			Zn	Fe	Cu	Mn
Winter	0-20	RD-0 (Regulator)	3.01 a	6.88 l	1.22 z	0.39 z
		RD-30	2.92 b	10.87 a	1.35 z	0.94 cd
		RD-50	2.89 c	9.88 b	1.66 o	0.85 hi
		RD70	2.60 g	9.25 c	1.80 k	0.84 ij
		RD-90	2.45 j	8.67 d	1.84 j	0.76 m
		RD-110	2.35 l	7.98 f	1.83 j	0.57 w
		RD-130	2.18 s	7.65 gh	1.98 f	0.53 xm
	20-40	RD-0 (Regulator)	2.91 bc	5.87 pq	1.13 z	0.34 z
		RD-30	2.74 ef	8.66 d	1.16 z	0.83 j
		RD-50	2.53 h	8.24 e	1.36 yz	0.68 p
		RD70	2.32 m	7.97 f	1.45 u	0.65 rs
		RD-90	2.17 s	7.41 ij	1.53 s	0.59 v
		RD-110	1.98 u	6.49 mn	1.76 l	0.47 z
		RD-130	1.92 v	6.26 o	1.79 k	0.43 z
	40-60	RD-0 (Regulator)	2.23 pq	5.34 rs	0.98 z	0.31 z
		RD-30	2.18 s	6.57 m	1.09 z	0.63 tu
		RD-50	1.98 u	6.46 mn	1.16 z	0.56 w
		RD70	1.92 v	5.98 p	1.22 z	0.53 x
		RD-90	1.85 wx	5.36 rs	1.28 z	0.45 z
		RD-110	1.65 z	4.893vx	1.36 yz	0.37 z
		RD-130	1.58 z	4.35 z	1.40 v	0.33 z
Spring	0-20	RD-0 (Regulator)	2.43 j	4.88 v-x	1.35 yz	0.49 y
		RD-30	2.38 k	7.77 g	1.45 u	0.97 b
		RD-50	2.28 n	7.29 jk	1.87 i	0.95 c
		RD70	2.19 rs	7.22 k	1.94 h	0.88 ef
		RD-90	2.19 rs	6.89 l	2.01 e	0.83 j
		RD-110	2.18 s	5.97 p	2.28 c	0.65 rs
		RD-130	1.98 u	5.88 pq	2.31 b	0.63 tu
	20-40	RD-0 (Regulator)	2.35 l	4.54 z	1.22 z	0.44 z
		RD-30	2.62 g	6.36 no	1.34 z	0.88 ef
		RD-50	2.11 t	6.21 o	1.55 r	0.79 k
		RD70	1.98 u	5.79 q	1.67 no	0.74 n
		RD-90	1.93 v	5.22 st	1.76 l	0.68 p
		RD-110	1.87 w	5.13 tu	1.88 i	0.53 x
		RD-130	1.84 x	5.22 st	1.88 i	0.48 yz
	40-60	RD-0 (Regulator)	1.86 wx	3.88 z	1.13 z	0.40 z
		RD-30	1.74 z	5.35 rs	1.17 z	0.79 k
		RD-50	1.54 z	5.19 st	1.28 z	0.66 qr
		RD70	1.42 z	4.87 v-x	1.39 vw	0.64 st
		RD-90	1.39 z	4.46 z	1.45 u	0.63 tu
		RD-110	1.18 z	4.36 z	1.56 r	0.47 z
		RD-130	1.150 z	4.56 z	1.59 q	0.41 z
LSD (5%)			0.02342	0.1571	0.01656	0.01656
SE			0.0082	0.0547	0.0058	0.0057
*FAO (1985)			2.0	5.0	0.22	0.23

were not within the permissible limits of FAO for agriculture purpose.

The soil samples collected from Phuleli Canal Command area at various sites (Table **2**) revealed significantly ($P<0.05$) different trace metals content of Zn, Fe, Cu and Mn. The results of the study indicated higher Zn (2.39 ppm) content in soil of canal command area near upper reach site and lower Zn (1.68 ppm) content was observed near down reach site (RD-130). However, the minimum Fe (4.92 ppm) and Mn (0.42 ppm) was noted near RD-0 that were increased to 7.14 ppm and 0.88 ppm respectively near RD-30. Further decreasing trend was observed near mid to down reach sites (RD-50 to RD-130) of Phuleli Canal Command area. Whereas, the lowest content of Cu (1.21 ppm) was observed near upper reach site (RD-0) and values increased near down reach site (RD-130). Cu and Mn content in soil were found higher than the FAO permissible limits in all locations. But Zn was not within the permissible limit of FAO at upper reach sites only. Similarly Fe was noted higher in all locations except upper reach site (Table **2**).

Interactive effect of seasons x soil depths x locations in the Command area of Phuleli Canal (Table **3A-B**) showed that the Zn (3.01 ppm) content in soil was higher in upper soil layer (0-20 cm) during winter near upper reach site (RD-0), whereas, it decreased (1.02 ppm) in lower soil depth (20-40 cm) towards down reach site near RD-130 during summer. However, Fe (10.87 ppm) was higher in upper soil layer (0-20 cm) near RD-30 during winter season and it decreased (2.87 ppm) in lower soil depths (40-60 cm) near upper reach site (RD-0) during summer. While, Cu (2.41 ppm) was higher in upper soil layer (0-20 cm) near down reach site (RD-130) during summer and it decreased (0.98 ppm) in lower soil depths (40-60 cm) near upper reach site (RD-0) during winter season (Table **3A-B**). However Mn (1.21 ppm) was higher in upper soil layer (0-20 cm) near RD-30 during summer and it decreased (0.31 ppm) in lower soil depths (40-60 cm) near upper reach site (RD-0) during winter.

Zinc content in soil samples was relatively higher than FAO permissible limits during winter in all soil layers and locations during autumn and became in spring and summer in upper soil layers and were greater than the permissible limit of FAO. Fe content in soil samples was higher than FAO permissible limits during winter, autumn and spring in lower soil layers (40-60 cm) near down reach site. whereas, in summer season it was relatively more in upper soil layers near mid to down reach sites and was not within the permissible limits of FAO. Same was true with Cu and Mn, which were not within the permissible limit of FAO for crop production. While irrespective of seasons and soil depths, the Fe was significantly higher than FAO recommendations except lower depth (40-60 cm) during summer and spring seasons. Similarly, Cu, Mn, Cd and Cr were considerably higher than the permissible limits of FAO. The chemical analysis of soil indicated that the Zn, Cu, Fe, Cd, Cr contents were relatively higher than the FAO permissible limits while Pb and As were within the recommended limits (Table **3A-B**).

DISCUSSION

In this study, it was observed that trace elements (Fe and Zn) contents in soil were more in winter except Cu and Mn than in summer. The seasonal variations may be due to either anthropogenic causes, such as irrigation or wastewater discharge, or natural causes, such as water temperature, pH, redox condition, water flux, or activity of microorganisms [19]. The accumulation of these elements in soils and crops may become health hazards to humans and/or animals. Therefore, continued assessment of the concentrations of potentially toxic elements in soil and plants and/or treatment of sewage water before using for irrigation is needed [20].

This study shows that Cu and Mn contents in soil was higher than the permissible limits of FAO [14] for agriculture purpose at most of the locations. Manganese becomes insoluble under alkaline conditions. The deficiencies are more likely common in calcareous and alkaline soils [21]. Further, this study shows that Zn was not within the permissible limit of FAO at upper reach sites only. Similarly Fe was noted higher in all locations except upper reach site. However, High content of Fe can precipitate the dissolved phosphate thus reducing the uptake of phosphorous in plants [22].

CONCLUSIONS

Seasonal variability in trace metals revealed that Zn and Fe contents found higher during winter season. As the season changed the values of these parameters showed decreasing trend (autumn>spring>summer). However, Cu and Mn contents were found higher in summer and were lower in spring, autumn and winter. Contents of Cu and Mn with respect to seasons and locations were not within the permissible limits of FAO for agriculture purpose. Whereas, Zn was not within the permissible limit of FAO at upper reach sites only.

Similarly Fe was noted higher in all sites except upper reach site.

It was also found that trace elements contents higher in soils at most of the locations for crop production under Phuleli Canal Command area were mainly produced from various pollution sources *viz,* industrial and municipal liquid effluents. It is recommended that instead of discharge municipal sewage water directly into the canal and its command area, it should be partly treated and then employed for the urban agriculture. Thus, industries must be bound lawfully to suspend draining toxic effluents directly into the canal. Regular monitoring should be carried out for contamination of the canal water quality for healthy environment of command area. Awareness programs among local people should be started/initiated.

ACKNOWLEDGEMENTS

The authors are highly thankful to Drainage and Reclamation Institute of Pakistan, Tandojam for providing laboratory facilities for the analyses of trace elements.

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Received on 11-05-2015 Accepted on 19-10-2015 Published on 24-11-2015

http://dx.doi.org/10.6000/1927-5129.2015.11.81