Monitoring of Industrial Waste Disposal by the use of Computer-developed Models: A Case Study of the Jakara Waste-water Channel in Kano Metropolis, Kano State, Nigeria

Timothy Akpomie[1*] Eno Ekanem[2] Mohammed Adamu[3]
1.Quality Control Department, Entel Water, Km 7 Zaria Road Jos, Plateau State
2.Chemistry Programme, Abubakar Tafawa Balewa University Bauchi, Bauchi State, Nigeria
3.Maths & Statistic Programme, Abubakar Tafawa Balewa University Bauchi, Bauchi State, Nigeria

Abstract
The concentrations of four heavy metals (Fe, Cd, Cu and Pb), from a previous study, on the determination of pollutants in waste-water samples along the Jakara waste-water channel in Kano metropolis were modelled using the Minitab statistical software. This was with the view of obtaining a model that would estimate and forecast the extent of pollution by the continuous discharge of industrial sewage on the canal. Though the initial concentrations of these metals were higher than the acceptable limits for sewage disposal by the World health organization (WHO), the obtained models showed that the concentrations of the respective heavy metals were increasing in a quadratic manner with time. Furthermore, from an initial concentration of 21.45, 3.58, 3.78 and 2.87mg/l for each respective heavy metal in the year 2008, the obtained models forecasted the concentrations at 95% confidence level, to be 15, 56, 30 and 35 times higher than their initial concentrations respectively by the year 2013. Finally, the order for this bioaccumulation was found to be Cd > Pb > Cu > Fe. The predicted concentrations would be indicative of the degree of bioaccumulation of these metals by vegetables if irrigated from this wastewater source.
Keywords: Bio-accumulation, Bio-magnification, Chemometrics, geo-accumulation, Models, waste-water

Introduction
The problem of environmental pollution due to toxic metals emanating from improper industrial sewage disposal is now a major source of concern in most metropolitan cities. These toxic heavy metals, which include, Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd, As, Ni, Pb etc entering the ecosystem may lead to geoaccumulation, bioaccumulation and biomagnification. However, some of these heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological systems, their deficiencies or excesses could lead to a number of disorders, (Wu, 1995). Sewage effluents of municipal origin has been reported to contain appreciable amount of major essential plant nutrients and therefore the fertility levels of the soils are improved considerably under sewage irrigation of crop fields, (Thomann & Mueller 1987). However, further studies by (Kashefipour, 2004), showed that, the presence of toxic heavy metals like Fe, Pb and Hg reduce soil fertility and agricultural output. Additionally, treated sewage water also contains variable amounts of heavy metals such as Pb, Ni, Cd, Cu Hg, Zn and Cr, which have the potential to contaminate crops growing under such irrigation. The method of Chemo-metrics was used in monitoring this contamination.

Chemometrics is the science of extracting information from chemical systems by data-driven means (Wikipedia, 2012). It is a highly interfacial discipline, using methods frequently employed in core data-analytic disciplines such as multivariate statistics, applied mathematics, and computer science, in order to address problems in chemistry, biochemistry, medicine, biology and chemical engineering. The main attraction of such models, in contrast with physical models, is their low cost and their ease of adaptability to new situations such as temperature, pH, and salinity changes (Orlob 1983). The developed models would be by special chemometric-computer software such as the Minitab-11 or 15 and even more recently, 17. The techniques used in chemometrics include;

1. Multivariate calibration
2. Classification, pattern recognition, clustering
3. Multivariate curve resolution
4. Other techniques.

For the purpose of this research, the multivariate calibration was used. Here, appropriate models were developed which could be used to predict the properties of interest based on measured properties of chemical system, such as pressure, flow, temperature, pH and so on. In this method, many chemical problems and applications involve calibration. The objective is to develop models which can be used to predict properties of interest based on measured properties of the chemical system like pressure, flow rate, temperature, infrared, Raman, NMR spectra and mass spectra.

1. Methology
Results of several spectrophotometric measurements of the Concentrations of Fe, Cd, Cu and Pb at different pH and temperature was modelled using the Minitab statistical software into time-series (quadratic) and simple multi-

linear regression models (Minitab 11, 1996).

2. Results and Discussion

Figure 1 is a graphical representation of the concentration of Fe in the wastewater channel. The overall trend depicts the concentration of the heavy metal to be increasing with time. The model, ***Yt =25.195-5.655*t+0.915*t**2,*** quadratic in nature, could be used to forecast the metal concentration at any point in time. The other model, ***Fe (mg/l) = - 20.3 + 8.80 ph - 1.41 T (°C),*** multi-linear in nature in terms of pH and temperature, could also be used to estimate the concentration of the metal provided the changes in pH and temperature are measured. The error margin with this estimation is 1.4% implying very high reliability on the results.

By utilizing the quadratic model, the concentration of Fe from the year 2008 to same time this year (2013) would be about 321.75mg/l.

Cd, Cu and Pb also showed the same trend like that of Fe. Their respective concentrations were also increasing with time. Their respective models as shown beneath their respective figures were also highly error free except that for Cd, which was 5.6%. Even at this, the result was still reliable. Concentrations of Cd, Cu and Pb by the year 2013 would be 200.48, 113.4 and 100.45mg/l respectively using their respective quadratic models.

3. Conclusion

By using the developed Minitab computer model, the disposal of industrial waste at the Jakara wastewater channel could be investigated or Monitored. The Concentration of the heavy metals were increasing quadratically and were predicted to be about 15, 56, 30 and 35 times higher this year than five years ago when the measurements were made.

This is also a clear indication that the industries responsible for these discharges were or may not be treating them before doing so. The dangers of such practices are unimaginable as this portends danger to the citizenry because of metal accumulation by plants and animals alike. Cd was the most accumulating heavy metal while Fe was the least.

4. Acknowledgement

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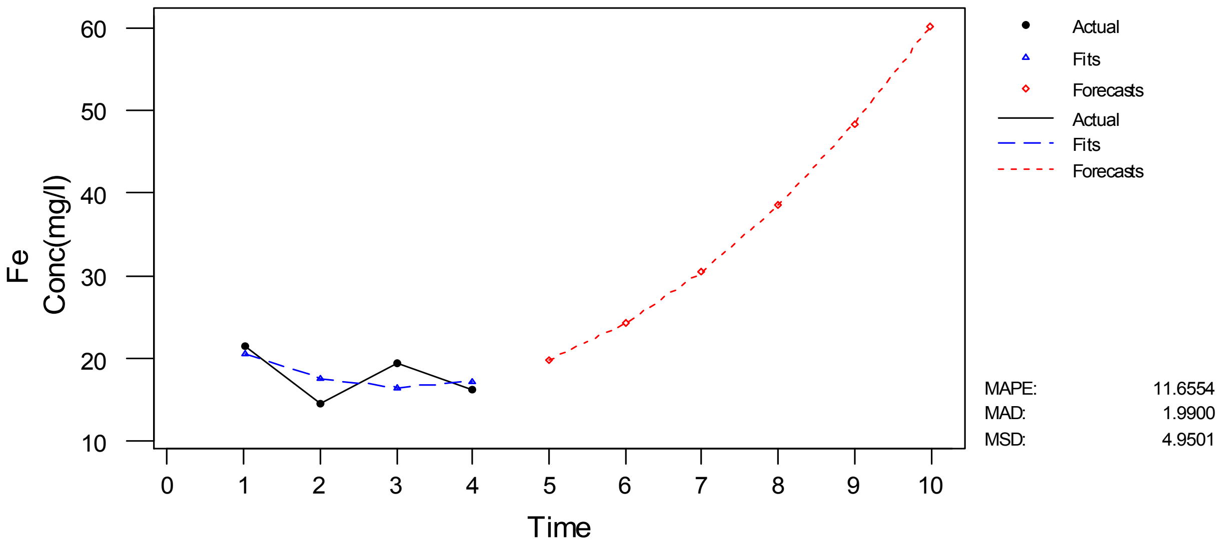

Figure 1

Yt =25.195-5.655*t+0.915*t**2

R-Sq(adj) = 98.6%

Fe (mg/l) = -20.3 + 8.80 pH – 1.41 T (^0C)

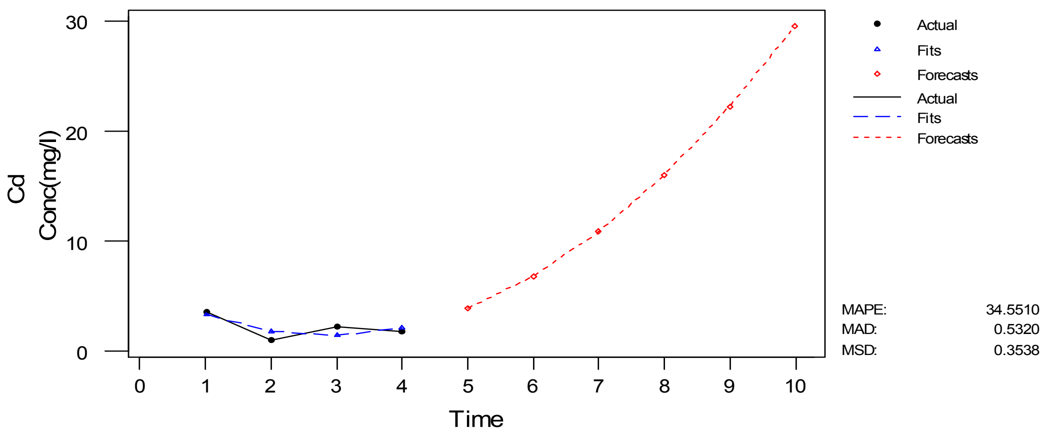

Figure 2

R-Sq(adj) = 94.4%

Cd (mg/l) = - 7.78 + 3.26 pH - 0.652 T (^oC)

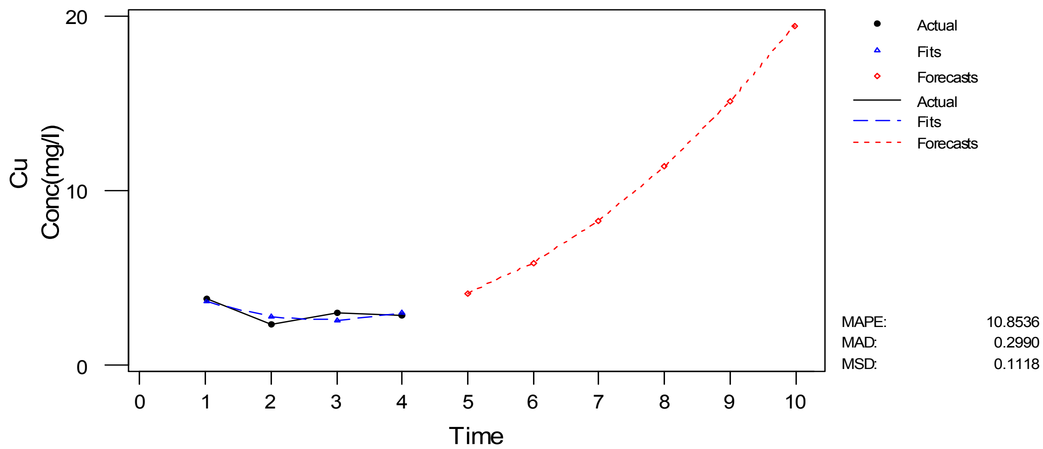

Figure 3

Yt =5.1475-1.8445*t+0.3275*t**2

R-Sq(adj) = 89.5%

Cu (mg/l) = - 2.66 + 1.81 pH - 0.357 T (^oC)

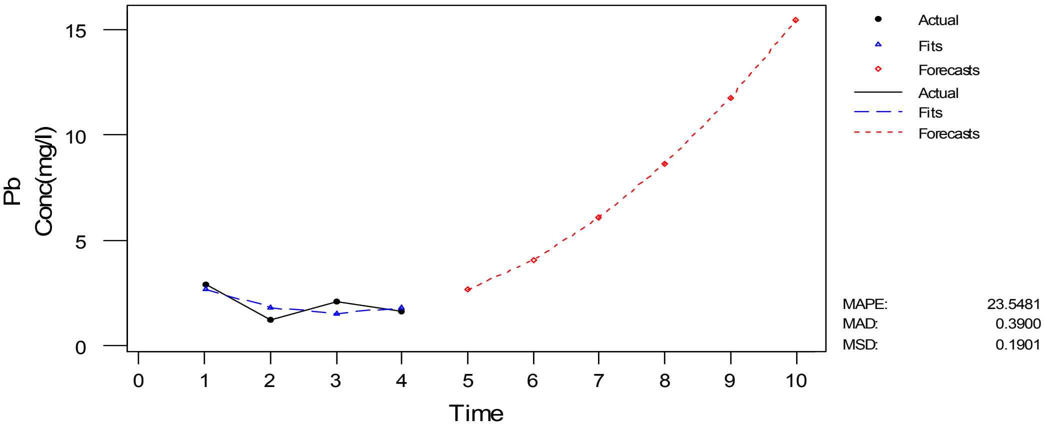

Figure 4

Yt = 4.105-1.715*t+0.285*t**2

R-Sq(adj) = 100.0%

Pb (mg/l) = - 5.31 + 2.14 pH - 0.404 T (°C)

Time-series plots for Mean Concentration of heavy metals in Jakara Waste-water Channel of Kano

Table 1: Mean Concentration of pollutants (Heavy metals) in Jakara wastewater channel in Kano state, Nigeria

Sampling Point	pH	Temperature (^{0}C)	Mean Heavy metal Concentration (mg/l)			
			Fe	Cd	Cu	Pb
1	9.94±1.32	32.34±0.32	21.45	3.58	3.78	2.87
2	8.94±2.03	31.11±0.11	14.56	1.00	2.32	1.23
3	10.34±1.43	36.34±2.94	19.45	2.19	3.01	2.11
4	9.54±0.54	33.34±1.44	16.22	1.83	2.86	1.61