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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

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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, Chemo metrics, geo-accumulation, Models, waste-water

1. 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 geo-accumulation, bioaccumulation and bio-magnification irrespective of the naturally occurring and environmental bio-degradation activities. 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.

Chemo metrics 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 chemo metric-computer software such as the Minitab-11 or 15 and even more recently, 17. The techniques used in chemo metrics include;

a. Multivariate calibration
b. Classification, pattern recognition, clustering
c. Multivariate curve resolution
d. 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.

2. Methodology

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).

3. Results and Discussion

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

Table 1 shows the mean concentration of the four heavy metals and their corresponding pH and temperatures at the four different sampling points. These data, with the aid of the computer statistical software, were used to develop the respective models for each heavy metal as shown in the figures below;

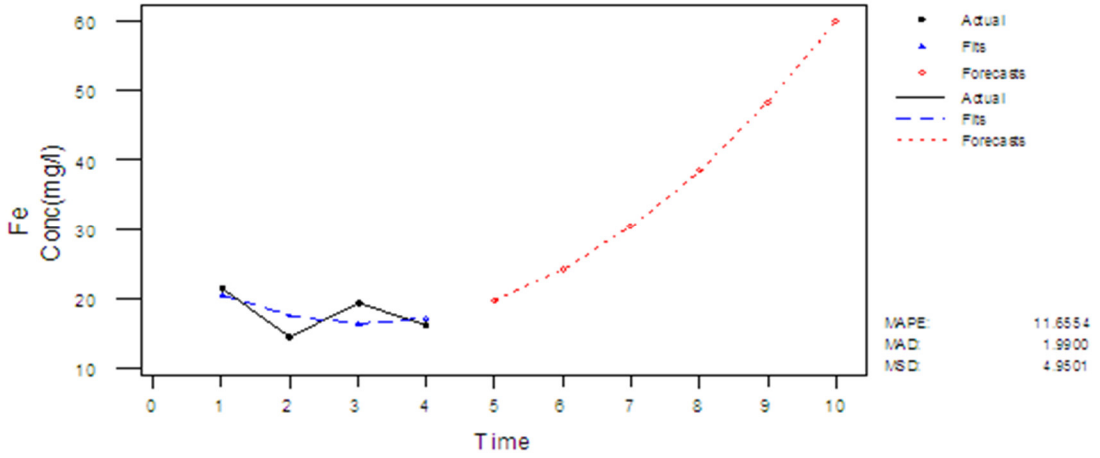

Figure 1: The Trend of the Concentration of Fe Discharged at the Waste-Water Channel

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, automatically generated by the software and computer ***Yt =25.195-5.655*t+0.915*t**2*** and 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 (^{0}C),*** multi-linear in nature in terms of pH and temperature and also auto-generated, could also be used to estimate the concentration of the metal provided the changes in pH and temperature were measured. The error margin with this estimation was 1.4% implying very high reliability on the results.

By the utilization of the quadratic model, the concentration of Fe from the year 2008 to same time (2013) was evaluated to be 321.75mg/l.

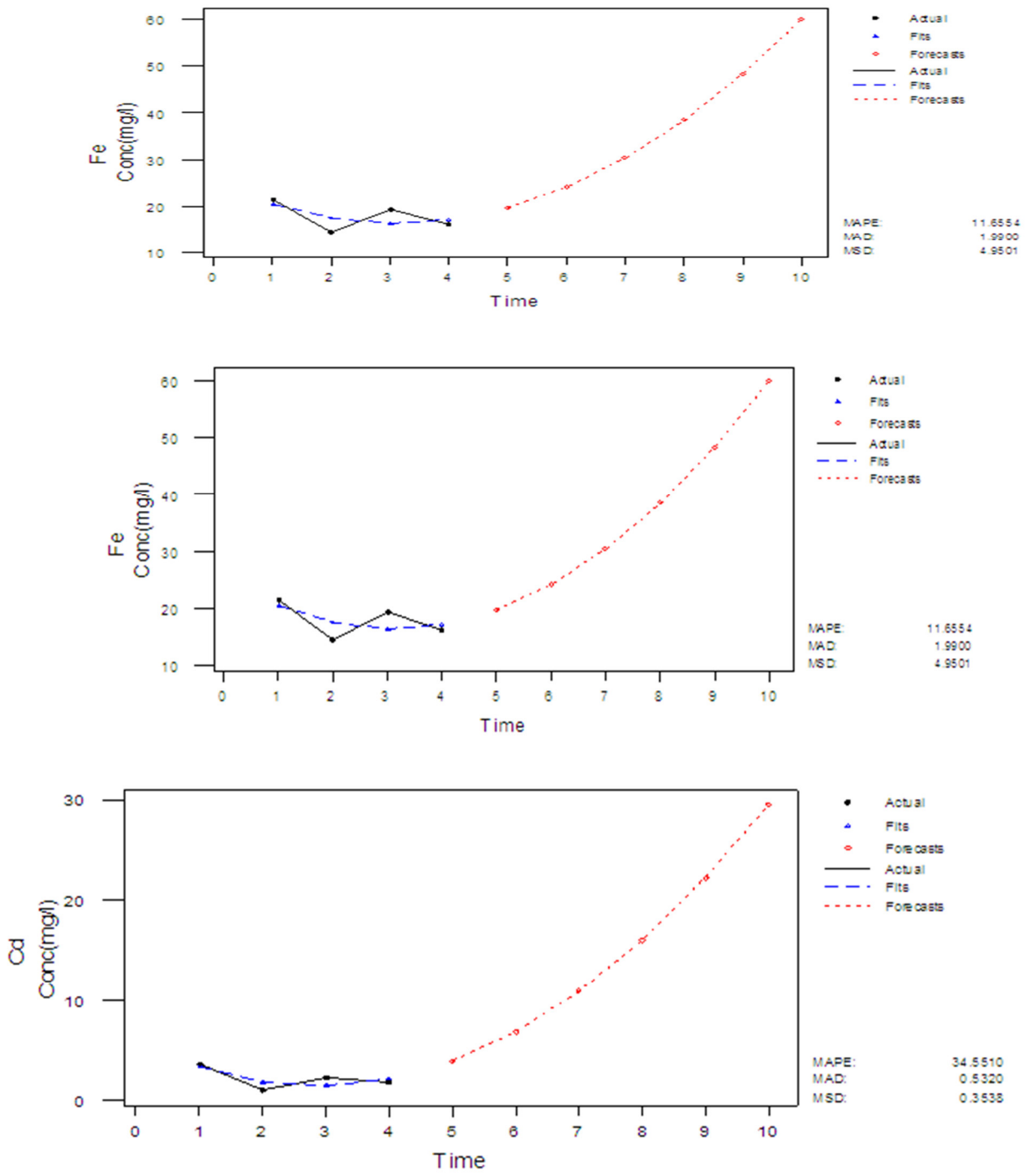

Figure 2: The Trend of the Concentration of Cd Discharged at the Waste-Water Channel
Here, the developed model was generated to be Cd (mg/l) = - 7.78 + 3.26 pH - 0.652 T (^{0}C)

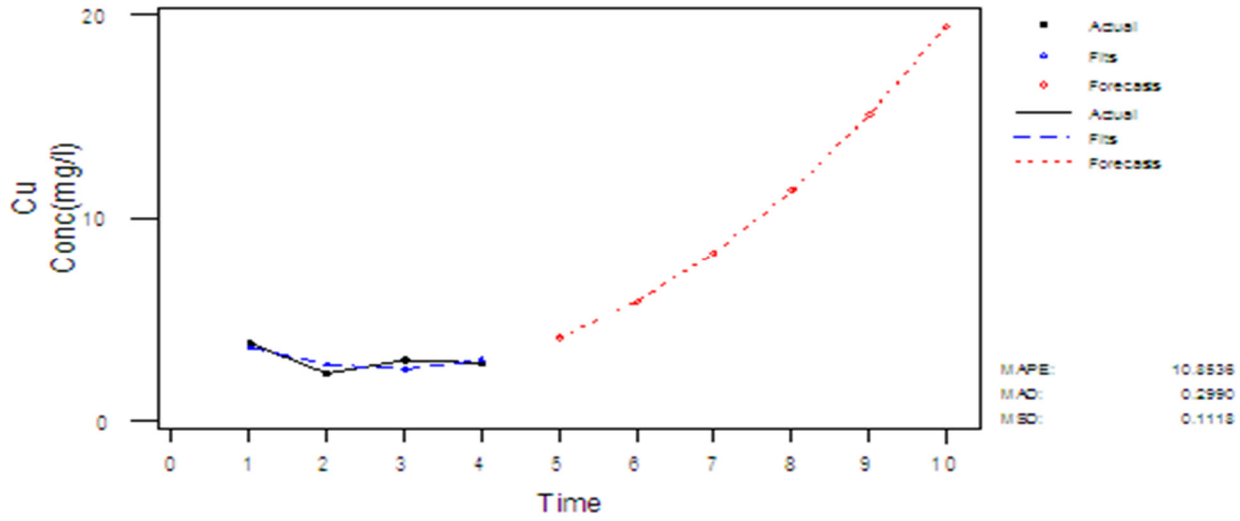

Figure 3: The Trend of the Concentration of Cu Discharged at the Waste-Water Channel

The developed model for forecasting the concentration of this heavy metal was found to be: Cu (mg/l) = - 2.66 + 1.81 pH - 0.357 T (^{0}C) and it's coefficient of correlation was 89.5%.

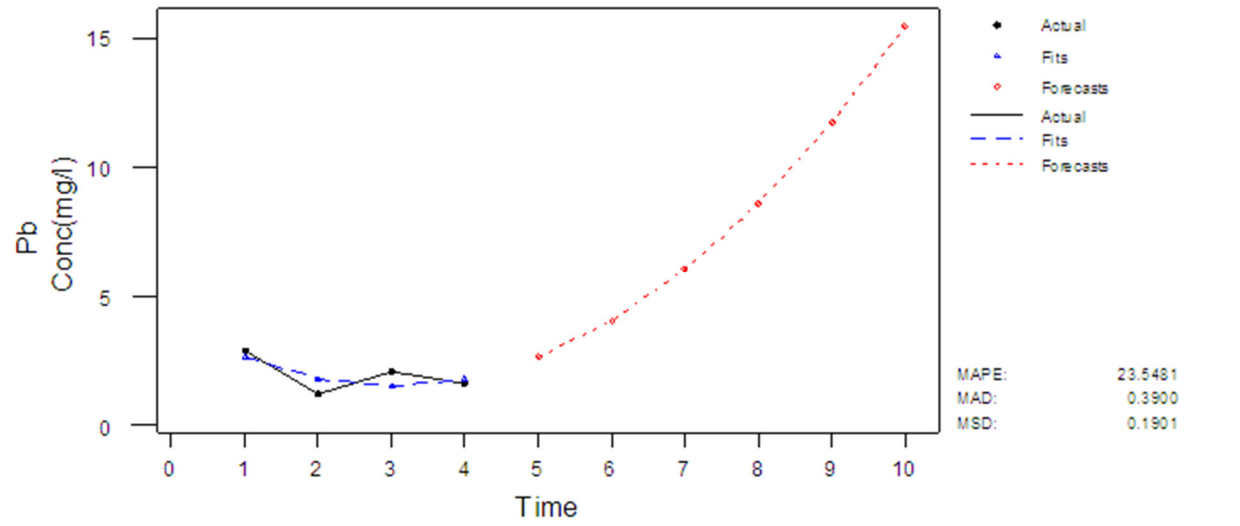

Figure 4: The Trend of the Concentration of Pb Discharged at the Waste-Water Channel

The model for lead was obtained as; Pb (mg/l) = - 5.31 + 2.14 pH - 0.404 T (^{0}C) and the coefficient of correlation was remarkably one hundred percent.

Thus, Cd, Cu and Pb also showed similar trend like that of Fe. That is, their respective concentrations were also increasing with time. Furthermore, their respective models were also highly error free except that for Cd, which was 5.6%. Even at that, the result was still reliable. Finally, the Concentrations of Cd, Cu and Pb by the year 2013 were similarly evaluated using their respective models to be 200.48, 113.4 and 100.45mg/l which were indicative of their rising concentrations.

4. 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 respectively 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.

5. Acknowledgement
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