Journal of Environments
ISSN: 2313-660X
Vol. 1, No. 2, 54-59, 2014
http://www.asianonlinejournals.com/index.php/JOEN

Sources and Pathway of Environmental Pollutants into Surface Water Resources: A Review

Adamu Mustapha[1] --- Balarabe Usman Getso[2]

[1]Department of Geography, Kano University of Science and Technology, Wudil, Kano State, Nigeria
[2]Department of Biology, Kano University of Science and Technology, Wudil, Kano State, Nigeria

Abstract

Surface water pollution could threaten human, animal and ecosystem. Global human population and urban development are increasing at unprecedented rates, thereby creating havoc to the surface water quality. This study aims at reviewing some recent studies on sources and pathway of environmental pollutants into surface water resources. The review discusses point and non-point, natural and anthropogenic sources of surface water pollution. Further, it highlighted some influence of land use and land cover changes on the surface water resources. This review recommended that Public should be enlightened and educated by the regulatory authority regarding the danger of rampant disposal of domestic and industrial wastes into surface water resource which will help to reduce the pollutant loads.

Keyword: Water Pollution; Anthropogenic Influence, Point and Non-Point Pollution; Agricultural Waste, Municipal Waste, Industrial Effluent

1. Introduction

During recent years, there has been increasing awareness of, and concern about, surface water pollution all over the world [1]. Surface water pollution is a serious problem today, in spite of all effort to control it. The Environmental Protection Agency (EPA) estimates that approximately one third of all surface water in the world is unsafe for various activities. This means that, the importance of water as natural resources requires careful management and conservation which must be universally recognized. Although nature often has great ability to recover from environmental damage, the growing demands on water resources necessitate the professional application of fundamental knowledge to ensure the maintenance of water quality and quantity [2].

Waste materials including liquid are the by-products of human activities which may be treated or untreated before being disposed off. Waste generally has assumed exponential increases and as a result of rapid growth of population and development in the urban centers where large volume of waste are generated due to multiple productions of goods in the industrial and agricultural sectors [3] . Waste products are discarded in three main forms (solid, liquid and gaseous), but the most widespread disposal state is liquid, because both solid and gaseous waste can be eventually transformed through hydrological cycle and transported through water course [4]. Water is the most important natural resource in the world, since without it life cannot exist and most industries cannot operate [5]. Surface water quality is a term used to describe the physical, chemical and biological characteristics of water. These attributes affect water suitability for human consumption (drinking, irrigation and industrial) and ecosystem health [6]. The most common physical characteristics of water are colour, temperature, taste, odour, turbidity. The chemical constituent of water are substances that dissolve in water including gases (e.g, oxygen and carbon dioxide), metals (Chromium, lead, copper, cobalt), nutrients (nitrogen and phosphorus), pesticides (altrazine and endosulfan) and other organic compounds (poly-chlorinated bi phenyl) [7] . Biological constituents of water are living organism including bacteria, virus, protozoan, insects, plant and fish [8].

Nutrients in surface water mainly come from various sources including domestic sewage, industrial waste water, livestock and poultry breeding excretion, aquaculture by-products, groundwater, surface run-off and atmospheric inputs [9]. Fresh water can be impacted through inputs from industrial, domestic, agricultural activities, sewage discharge, groundwater leaching and run off [10, 11].

2. Point and Non Point Water Pollution Sources

There are various ways through which environmental pollutants enter into the surface water resources, either through point and non-point sources. Point source of water pollution occurs when the polluting substance is emitted directly in to the ways, such as drain pipes, ditches or sewer outfall, point sources are discrete and relatively easy to monitor and treat with discharge that are uniform throughout the year [12] . Point source of water pollution tend to be continuous, with little variability over time in which they can be monitored by measuring discharge and chemical concentrations periodically at a single area/region.

The point sources includes waste water discharge from municipal and industrial, run-off and leachate from waste disposal site, run-off from animal feed lots, run-off from mines, oil fields, un-sewerage industrial site, storm sewer outfalls from cities, overflow of combined storm and sanitary sewers, run-off from construction sites among others. In most of the developing countries, urban and industrial waste are generally disposed off without adequate treatment which resulted in exacerbating foreseeable fresh water resources [13, 14]. The non-point source of water pollution includes run-off from agricultural (including returns flow from irrigated agriculture), run-off from pasture and range field, septic tank leachate and run-off from failed septic systems, run-off from construction sites, activities on the land that generate contaminants such as wetland conversion, development of land or water ways [15].

Non-point pollution is diffused sources of pollution, having no definite or specific location where discharge into a body of water. For example, farm field, parking lots, construction sites and agricultural field. These sources are often difficult to monitor, regulate or treat [8] . The non-point source of water pollution are often intermittent and linked to seasonal agricultural activities, they are derived from extensive area of land and are transported overland, underground, or through the atmosphere to receiving water [16]. Diffuse sources of suspended sediments, nutrients and pathogens in agricultural and urban areas are often difficult to quantify and measure [16]. The cause of water quality deterioration is mostly associated with diffuse source of pollution. Non-point sources of water pollution are mainly carried away by rainstorm run-off [17] and nutrients are predominate variables washed through non-point pollutions [18].

Surface water pollution is generated by domestic waste through dumping of biodegradable organic pollutants, nutrient and bacteria, industrial effluent discharge through release of organic and inorganic parameters or urban and agricultural through pollutants coming from the drainage of areas containing fertilizer, agricultural pesticides, animal faeces and suspended materials [18]. The quality of surface water within a region is governed by anthropogenic activities (urban, industrial, and agricultural activities and the human exploitation of water resources) and natural processes (precipitation rate, weathering, soil erosion, mineral deposits, emission from active volcanoes, sea salt sprays, forest fire, etc.). The possible variability in water quality may be due to anthropogenic activities, natural variance during seasons due to various biochemical or chemical processes [19].

3. Anthropogenic Sources of Water Pollution

The rapid urbanization, industrialization, intensive agriculture and growing demand for energy have adversely affected the physiochemical parameters of surface water [20]. The anthropogenic influences involves organic waters from industrial plant, municipal and industrial waste water discharge (point as well as non-point sources of pollution) as presented in Figure 1 which constitutes the constant polluting source of river water quality.

Water pollution can be directly linked to the type of waste water produced by urban, industrial and agricultural activities that flows in to the surface water [21]. Mining and smelting operation, disposal of treated and untreated waste effluents as well as metal chelate from different industries, including leather, petrochemical, and battery production, along with indiscriminate use of heavy metals containing fertilizers and pesticides in agricultural practices are example from long list of anthropogenic influence of surface water pollution [22].

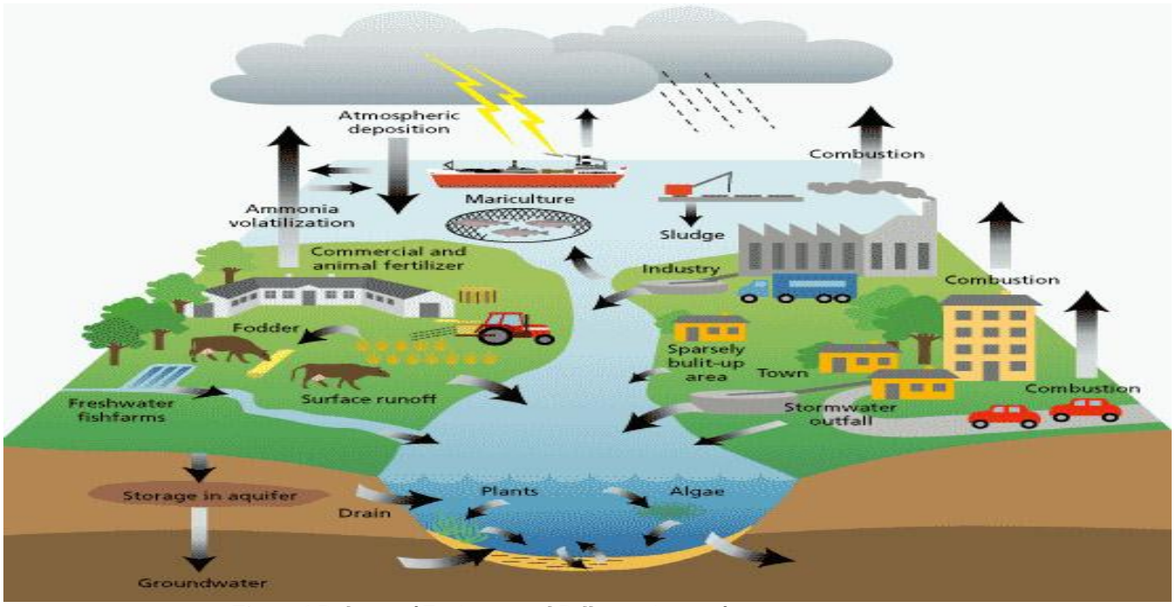

Figure-1. Pathway of Environmental Pollutants into surface water resources

3.1. Industrial Sources of Surface Water Pollution

Industrial pollution is one of the problem facing surface water resources and effluent generated by the industries is one of the sources of surface water pollution. Several studies conducted revealed that a significant relationship exists between industries and heavy metal concentration [4, 12, 23, 24].

The world global growth and rapid industrial development have led to a recognition and increasing understanding of interrelationship between pollution and environment. While almost industrial activities cause some pollution and produce waste, relatively few industries (without pollution control and waste treatment) are responsible for the bulk of pollution. In recent time, industrialization has transformed the natural environment, and the environment become hostile, posing threat to health and welfare due to the release of pollutants from industries [25]. The effluents discharged from industries may find their way into surface water bodies via canals and eventually the surface water bodies, such as lagoon, lakes, ponds, and rivers received pollutants and become vulnerable [26]. In developing countries, most industries dispose their effluents without treatment, and these effluents have a hazard effect on water quality, habitat quality, and complex effects on flowing waters [27].

Industrial waste generally has assumed exponential increases as a result of rapid growth of industrial development in the urban centers where large volume of effluent are generated due to multiple production of goods in the industrial sectors [28]. Surface water of many industrial countries is becoming heavily polluted by industrial effluent which is either directly discharge or partially treated into the water body. Polluting industrial discharges and waste water are one of the main causes of irreversible ecosystem degradation [29].

Some industrial waste contains poisonous chemicals which may become dangerous to the surface water and most of these wastes from the industries contain heavy metals. Heavy metals are among the most toxic pollutants present in marine, groundwater and industrial waste water. These heavy metals are of particular concern in surface water quality as a result of their environmental persistent, bio-geochemical recycling and biological risks [18]. Elevated levels of heavy metal concentrations in surface water are ubiquitous as a result of a wide range of human activities as well as natural geochemical processes which contaminate the surface environment. Disposal of sewage to the surface water become a necessity as soon as industries are established, the outcome was a deterioration of standard of many rivers and their water become useless for either domestic consumption or industrial uses [30]. Depending on the type and amount of effluent being generated from different type of industries, it could be concluded that, areas that find its location close to industries are heavily polluted with industrial effluents and produce greater negative effects on the environment.

3.2. Domestic Sources of Surface Water Pollution

With the growth of human populations and commercial activities, river water has received large amount of pollution from domestic/municipal source. Rapid population growth and associated urban development have led to the release of enteric human pathogens in to surface waters in many parts of the world [31]. Anthropogenic impacts directly affect watershed hydrology and the energy balance in the water and biochemical cycling in stream influence the water quality. Human activities have negatively influenced water quality and aquatic ecosystem functions. This has generated great pressure on the ecosystem, resulting in a decrease of water quality and biodiversity [16]. Different pollutants are being released from the households ranging from detergents, oil and grease, and solids waste. These pollutants have negative effects on the surface water; they pollute the water and thus causing undesirable smells. Carpenter, et al. [15] has reported that domestic sewage has constant strength and pollution ability and it is the combination of grey water and municipal waste which may contain pathogens. In addition, domestic sewage has been reported to constitute suspended solids (such as partially disintegrated particles) and very small solids in colloidal forms, further domestic waste may contain large floating particles such as rags, plastic, clothing among others [19].

The problem associated with sewage disposal on surface water bodies have become a major problem of the urban world due to increase in human population and industrialization. In recent decades, population growth increases the domestic water use while municipal sewage run-off from urban areas increased and these have influence nutrient inputs many folds to the level of their natural occurrence, resulting in accelerated growth of algal bloom [15].

Domestic waste discharge into the surface water may accumulate large quantity of nutrients enrichment and stimulates eutrophication process and bioaccumulation of organic and inorganic compounds. Further, it may result in alteration and interaction among both aquatic flora and fauna. Eutrophication refers to the excessive accumulation of micro and macro flora in water bodies which is closely associated with increase in human activities in the catchment area [15]. The rate of eutrophication process has been rapidly accelerated in modern times due to human activities by increasing the rate at which nutrients and organic substances enter aquatic systems from the surrounding watershed.

Eutrophication is caused by both regional sources such as urban effluents, industrial discharges, and aquaculture activities as well as trans-boundary components such as agricultural runoffs, riverine outflows, and airborne nutrient deposition [5]. Physical factors such as geomorphology of the system, the mean depth of the water body and the prevailing current of the water are the main factors controlling the eutrophication process. Eutrophication can lead to excessive growth of algae, change in water color and ability of light penetration and subsequent oxygen depletion [3]. A major impact of eutrophication is the stimulation of algal growth and the production of harmful algal blooms which may have devastating economic impact on the surface water and ecological system.

3.3. Agricultural Sources of Surface Water Pollution

It is well known that agriculture is the single largest user of fresh water resource, using a global average of 70% of all surface water suppliers [7]. Agricultural activities is both cause and at the same time victim of water pollution. It is a cause through discharge of pollutants and sediments to the surface water and it is a victim through the use of waste water which contaminates crops and transmits diseases to consumers and farm workers. Normally, agricultural water pollutants are transported to aboveground or underground receiving streams by periodic storm water. Irrigation

and rain-fed agricultural activities practices may contributes pollutants mainly nutrients from excessive application of fertilizer to the crops [10]. The agricultural drainage water contain pesticides, fertilizers and effluent from industrial activities and run-off, in addition to sewage effluents and the presence of decaying plant and animal residues supply the surface water bodies with huge quantities of pollutants. Similarly, Kaown, et al. [32] reported that, agricultural activities have been shown to produce high nitrate and phosphate concentrations in many site of the world.

Kim, et al. [33] reported that, intensive agricultural activities through application of fertilizers and pesticides have deteriorates surface water quality. Nitrogen and Phosphorous are indispensable inputs for the sustainability of agriculture. However, nutrients losses have a number of environmental consequences. Nitrogen and phosphorous can negatively affect the quality of surface water. Agricultural activities that causes non-point source of pollution include poorly located or managed animal feeding operations; overgrazing; improper or excessive application of pesticides and fertilizer in agriculture. Pollutants that result from farming and ranching may include sediments, nutrients, pathogen, pesticides, metals and salts [15]. Farmers apply nutrients such as nitrogen, phosphorus, potassium in the form of chemical fertilizers, manure and sludge and they may also grow legumes and leave crop residues to enhance productions. These nutrients may be washed and find its way through non-point source of pollution to nearby surface and sub-surface water. Pesticides, herbicides and insecticides are used to kills agricultural pest; these chemicals may enter and contaminate water through direct application, run-off and atmospheric addition. Ma, et al. [13] reported a negative contribution of pesticides to the surface water pollution as a result of application of pesticides which may accumulates in the sediments through long range exposure and result in high concentration of nutrients in surface water. The concentrations of biologically available nitrogen and phosphorus may cause eutrophication which is known well to play a vital role in determining the ecological status of aquatic systems. An excess of these nutrients may lead to diverse problems such as harmful algal blooms, reduced water transparency, loss of oxygen, taste and odor problems, fish deaths and loss of biodiversity [15]. Nutrient enrichment seriously degrades aquatic ecosystems, impairing the use of water for drinking, industry, agriculture, recreation and other purpose. The most prevalent source of agricultural water pollution is soil that is washed off field. Rain water or run-off may carries loose soil particles and dumb them in to nearby surface water which can eventually cloud the water increase the level of sediment in water, reduces the amount of sunlight that reaches the aquatic plants [4].

4. Natural Sources of Surface Water Pollution

The quality of surface water in a region is also governed by the natural factors. The natural factors may include precipitation rate, weathering processes and soil erosion. Run-off is a seasonal phenomenon and is largely influenced by the climate in the basin. The quality of surface water varies from site to site and season to season due to variation in chemical composition which is highly depended on topography, climate and mineralogical composition of the of the bed rock. The most important natural influences on surface water are geology, hydrological and climate, since these affect the quantity and quality of water available and their influence is generally greatest when the available water quantities are low [3].Temperature is the main factors affecting almost all physico-chemical equilibrium and biological reaction and also increases water temperature which will enhance dissolution, solubility, degradation and evaporation.

5. The Influence of the Land Uses on Surface Water Quality

The release of waste water and effluent from various categories of land uses especially in urban areas is threatening the quality of surface water. Land use changes happening in the process of urbanization, industrialization and agricultural activities which can modify the surface characteristic of the watershed that influence run-off quality and quantity [34]. Land use change may be a single greatest factor affecting ecological resources. Surface water quality is generally linked to land use in a catchment and studies have been focusing on their relationship with water quality variables such as dissolved salts, suspended solids and nutrients. In recent years, there is a rapid declining in the availability of usable fresh water in terms of water quality and quantity due to unsustainable land use practices.

The phenomena of urbanization in Nigeria are on a scale more rapid than many African countries. This is accompanied by equally spectacular aerial expansion. Two reasons to explain these phenomena: Firstly, series of political and administrative decentralization have taken place in the country since 1967 and these exercises involved the creation of many urban nuclei. Secondly, the boom in the national economy principally brought about by the country's oil boom of 1973-78 accelerated urbanization of the population and the physical growth of the urban centres. Figure 2 showed satellite image of Kano Metropolitan in 2006. Kano metropolitan has expanded in size and consumes large areas of vegetated land use adjacent to the city, pushing the peri-urban fridges further and further away from the original city boundary. This urban sprawl has brought about havoc to the environment and water resources.

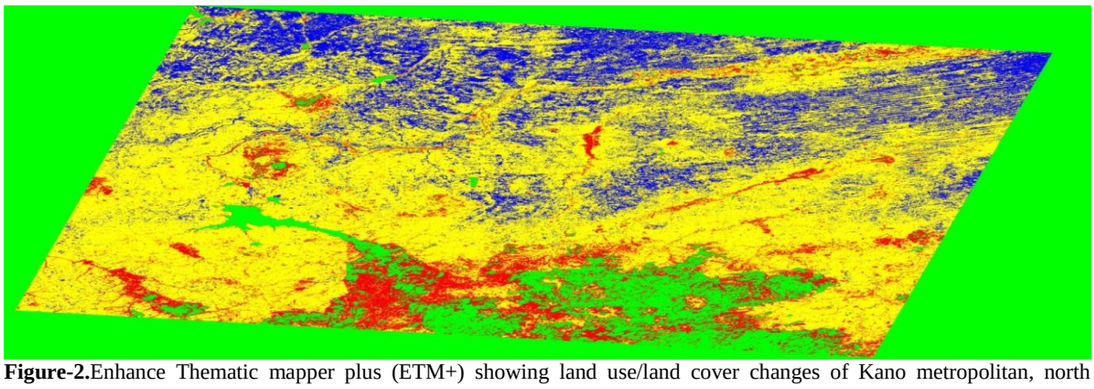

Figure-2. Enhance Thematic mapper plus (ETM+) showing land use/land cover changes of Kano metropolitan, north western Nigeria

Oluseyi [35] reported considerable changes in the land use in Ibadan Metropolitan of South-western Region of Nigeria. It was observed that, a dynamic change in the vegetation cover was consumed by residential low density sprawl development in the area. Land consumption rate (LCR) and land absorption rate (LAR) were determined in Abuja, Nigeria by Fanan, et al. [36] using Landsat imagery of 1987 and 2001 and Nigeriasat-1 imagery of 2006. The study revealed that, built-up areas increased and vegetation cover decreased at an alarming rate. The pattern of land use/land cover between 1975 and 2005 in Nigeria was extensively studied by Abbas [37], the study revealed a lost in the arable land. Table 2.1 showed drastic changes in some land uses and land cover changes in Nigeria between1975-2005.

Table-1. Land use and land cover changes in Nigeria between 1975 to 2005 in Km^2

Land use/land cover	1975	2005	% changes
Crop Plantations	824.15	1656	100.0
Alluvial	523.61	282.38	-46.1
Mangrove Forest	10157.12	1006731	-0.9
Riparian Forest	7506.46	13477.90	-29.0
Undisturbed Forest	28022.42	13477.90	-51.9
Urban built-up	1102.58	1362.37	23.6
Forested Fresh Water	18564.71	16696.51	-10.1
Irrigation Project	148.85	1008.86	577.8
Natural Water Bodies	6766.53	15588.36	130.4

Adopted after Abbas 2009 [38]

Rapid growth of urban land use has adversely affected the river ecosystem. Significant relationships between land use and water quality have been found in the watershed around the world by various researchers and the relationships might vary spatially, because watershed characteristics and pollution sources are not the same in different places. Population growth and urbanization pressure often lead to a more intensive land uses and subsequently accelerate the degradation of surface water quality.

Several researches conducted around the world revealed that land use activities have a profound influence on the receiving water resources quality. Urban land use especially in developing worlds are known to be the most important single land use that cause a substantial modification on the chemistry of surface water. Urban land use raised the concentrations of most of the water quality variables. Certain studies attempted to numerically quantify the relationship existed between land uses and water quality variation: for example [38] uses biological indicators and physico-chemical parameters to estimates the relationship between land use and surface water quality. Surface run off is a major source of non point pollution and is primarily responsible for the relationship between land use and water quality variation.

Water quality variation in relation to urban sprawl development in Georgia, USA was studied by Tu [39] to ascertain the relationship between spatial-temporal variation of water quality and land use. Six time period of land use data were obtained which includes four brand land use types of urban land, forest, agricultural and wet land. Water quality data from 1970 to 2009 were retrieved from United State Geological Survey (USGS) which includes fourteen water quality indicators from forty three sampling sites. The study showed that land use types of forest and urban land have change dramatically since 1970's and significant relationships were found between all the water quality indicators revealing the influence of land use changes. Spatial relationship of land use and water quality in receiving waters on a regional scale in the state of Ohio was evaluated by Tong and Chen [40]. The results revealed that, there is significant relationship between land use and in-stream water quality. Further, the results showed that agricultural and impervious urban lands produced a higher level of nutrients to the surface water body. Similarly, Mehaffey, et al. [41] examined the relationships between land cover and water quality in New York City's water supply watersheds. Results from their study demonstrated that significant relationships between surface water quality variation and the concentration of total nitrogen, total phosphorous and faecal coli form counts existed.

6. Conclusions

The trend of published research on sources and pathway of environmental pollutants into surface water resources increases tremendously. Effective water quality management requires that the concentration and effects of pollutants can be assessed accurately. Increased awareness of pollution and its effects has emphasized the importance of water quality management in maintaining our natural waters in a fit state for various purposes. Discharge from industries close to the surface water as well as domestic waste from residential areas should be reduced and monitored through the establishment of sewage treatment plants in major human settlements in the region, so that the functioning of the

ecosystem natural capability to degrade these waste will not be exceeded. This can be achieved by providing industries with modern treatment facilities and establishing central treatment plant by the government and enforcing that all waste from industries and residential areas must be fully treated before final disposal.

References

[1] S. Ahuja, *Handbook of water purity and quality*. New York: Academic Press, 2009.

[2] O. O. Ige and P. I. Olasehinde, "Preliminary assessment of water quality in Ayede-Ekiti, South-Western Nigeria," *Journal of Geology and Mining Research,* vol. 3, pp. 147–152, 2011.

[3] K. P. Singh, A. Malik, D. Mohan, and S. Sinha, "Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India): A case study," *Water Research,* vol. 38, pp. 3980–3992, 2004.

[4] F. A. Armah, S. Obiri, D. O. Yawson, E. E. Onumah, G. T. TYengoh, E. K. A. Afrifa, and J. O. Odoi, "Anthropogenic sources and environmentally relevant concentrations of heavy metals in surface water of a mining district in Ghana: a multivariate statistical approach," *Journal of Environmental Science and Health Part A,* vol. 45, pp. 1804–1813, 2010.

[5] T. H. Y. Tebbutt, "Principles of water quality control," *Butterworth-Heinemann,* 1988.

[6] Y. Li and K. Migliaccio, *Water quality concepts, sampling, and analyses*. Boca Raton, FL, USA: CRC Press, 2010.

[7] V. N. Chigor, V. J. Umoh, C. A. Okuofu, J. B. Ameh, E. O. Igbinosa, and A. I. Okoh, "Water quality assessment: surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard," *Environmental Monitoring and Assessment,* vol. 184, pp. 3389–3400, 2011.

[8] J. J. Peirce, R. F. Weiner, and P. A. Vesilind, "Environmental pollution and control," *A Butterworth-Heinemann,* 1998.

[9] J. Hu, Y. Qiao, L. Zhou, and S. Li, "Spatiotemporal distributions of nutrients in the downstream from Gezhouba Dam in Yangtze River, China," *Environmental Science and Pollution Research,* vol. 19, pp. 2849–2859, 2012.

[10] P. Palma, P. Alvarenga, V. L. Palma, R. M. Fernandes, A. M. V. Soares, and I. R. Barbosa, "Assessment of anthropogenic sources of water pollution using multivariate statistical techniques: A case study of the Alqueva's reservoir, Portugal," *Environmental monitoring and Assessment,* vol. 165, pp. 539–552, 2010.

[11] A. Mustapha and A. Z. Aris, "Spatial aspects of surface water quality in the Jakara Basin, Nigeria using chemometric analysis," *Journal of Environmental Science and Health, Part A,* vol. 47, pp. 1455–1465, 2012.

[12] D. D. Chiras, *Environmental science*. London UK: Jones & Bartlett, 2009.

[13] J. Ma, Z. Ding, G. Wei, H. Zhao, and T. Huang, "Sources of water pollution and evolution of water quality in the wuwei basin of Shiyang River, Northwest China," *Journal of Environmental Management,* vol. 90, pp. 1168–1177, 2009.

[14] A. Mustapha and A. Z. Aris, " Multivariate statistical analysis and environmental modeling of heavy metals pollution by industries," *Polish Journal of Environmental Studies,* vol. 21, pp. 1359-1367, 2012.

[15] S. R. Carpenter, N. F. Caraco, D. L. Correll, R. W. Howarth, A. N. Sharpley, and V. H. Smith, "Nonpoint pollution of surface waters with phosphorus and nitrogen," *Ecological Applications,* vol. 8, pp. 559–568, 1998.

[16] G. Mouri, S. Takizawa, and T. Oki, "Spatial and temporal variation in nutrient parameters in stream water in a rural-urban catchment, Shikoku, Japan: Effects of land cover and human impact," *Journal of Environmental Management,* vol. 92, pp. 1837–1848, 2011.

[17] N. M. Chong, Y. C. Chen, and C. N. Hsieh, "Assessment of the quality of stormwater from an industrial park in central Taiwan," *Environmental Monitoring and Assessment,* vol. 184, pp. 1801–1811, 2012.

[18] R. I. Silva Alves, O. Oliveira Cardoso, K. A. Abreu Tonani, F. C. Julião, T. M. B. Trevilato, and S. I. Segura-Muñoz, "Water quality of the Ribeirão preto stream, a watercourse under anthropogenic influence in the southeast of Brazil," *Environmental Monitoring and Assessment,* vol. 185, pp. 1151–1161, 2012.

[19] A. G. Awadallah and M. Yousry, "Identifying homogeneous water quality regions in the Nile River using multivariate statistical analysis," *Water Resources Management,* vol. 26, pp. 2039–2055, 2012.

[20] R. Avtar, P. Kumar, C. Singh, and S. Mukherjee, "A comparative study on hydrogeochemistry of Ken and Betwa Rivers of Bundelkhand using statistical approach," *Water Quality, Exposure and Health,* vol. 2, pp. 169–179, 2011.

[21] A. L. Vittori, C. Trivisano, C. Gessa, M. Gherardi, A. Simoni, G. Vianello, and N. Zamboni, "Quality of municipal wastewater compared to surface waters of the river and crtificial canal network in different areas of the eastern Po Valley (Italy)," *Water Quality, Exposure and Health,* vol. 2, pp. 1–13, 2010.

[22] V. Sheykhi and F. Moore, "Geochemical characterization of Kor River water quality, Fars province, Southwest Iran," *Water Quality, Exposure and Health,* vol. 4, pp. 25–38, 2012.

[23] A. Mustapha, "Identification of anthropogenic influences on water quality of Jakara River, Nothwestern Nigeria," *Journal of Applied Sciences in Environmental Sanitation,* vol. 7, pp. 11–20, 2012.

[24] J. Naumczyk and M. Rusiniak, "Physicochemical and chemical purification of tannery wastewaters," *Polish Journal of Environmental Studies,* vol. 14, pp. 789–797, 2005.

[25] F. W. Ntengwe, "Pollutant loads and water quality in streams of heavily populated and industrialized towns," *Physics and Chemistry of the Earth,* vol. 31, pp. 832–839, 2006.

[26] M. A. H. Bhuiyan, N. I. Suruvi, S. B. Dampare, M. A. Islam, S. B. Quraishi, S. Ganyaglo, and S. Suzuki, "Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka," *Bangladesh. Environmental Monitoring and Assessment,* vol. 175, pp. 633- 649, 2011.

[27] A. Cachada, M. E. Pereira, S. E. Ferreira, and A. C. Duarte, "Sources of potentially toxic elements and organic pollutants in an urban area subjected to an industrial impact," *Environmental Monitoring and Assessment,* vol. 184, pp. 15–32, 2011.

[28] G. S. Srinivasa and P. K. Govil, "Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India," *Environmental Monitoring and Assessment,* vol. 136, pp. 197–207, 2008.

[29] T. Rajaram and A. Das, "Water pollution by industrial effluents in India: Discharge scenarios and case for participatory ecosystem specific local regulation," *Futures,* vol. 40, pp. 56–69, 2008.

[30] A. Mustapha, A. Z. Aris, M. F. Ramli, and H. Juahir, "Temporal aspects of surface water quality variation using robust statistical tools," *The Scientific World Journal,* 2012.

[31] A. Mustapha and A. B. Nabegu, "Surface water pollution source identification using principal component analysis and factor analysis in Getsi River, Kano, Nigeria," *Australian Journal of Basic and Applied Sciences,* vol. 5, pp. 1507–1512, 2011.

[32] D. Kaown, Y. Hyun, G. O. Bae, C. W. Oh, and K. K. Lee, "Evaluation of spatiotemporal trends of groundwater quality in different land uses using kendall test," *Geosciences Journal,* vol. 16, pp. 65–75, 2012.

[33] J. H. Kim, C. M. Choi, S. B. Kim, and S. K. Kwun, "Water quality monitoring and multivariate statistical analysis for rural streams in South Korea," *Paddy and Water Environment,* vol. 7, pp. 197–208, 2009.

[34] J. Tu, "Spatially varying relationships between land use and water quality across an urbanization gradient explored by geographically weighted regression," *Applied Geography,* vol. 31, pp. 376–392, 2011.

[35] O. F. Oluseyi, "Urban land use change analysis of a traditional city from remote sensing data: The case of Ibadan metropolitan area, Nigeria," *Humanity and Social Sciences Journal,* vol. 1, pp. 42–64, 2006.

[36] U. Fanan, K. I. Dlama, and I. O. Oluseyi, "Urban expansion and vegetal cover loss in and around Nigerian Federal Capital City," *Journal of Ecology and the Natural Environment,* vol. 3, pp. 1–10, 2011.

[37] I. I. Abbas, "An overview of land cover changes in Nigeria, 1975-200," *Journal of Geography and Regional Planning,* vol. 2, pp. 062–065, 2009.

[38] X. Wang, "Integrating water quality management and land use planning in a watershed contex," *Journal of Environmental Management,* vol. 61, pp. 25–36, 2011.

[39] J. Tu, "Spatial and temporal relationships between water quality and land use in northern Georgia, USA," *Journal of Integrative Environmental Sciences*, vol. 8, pp. 151–170, 2011.

[40] S. T. Y. Tong and W. Chen, "Modeling the relationship between land use and surface water quality," *Journal of Environmental Management*, vol. 66, pp. 377–393, 2002.

[41] M. H. Mehaffey, M. S. Nash, T. G. Wade, D. W. Ebert, K. B. Jones, and A. Rager, "Linking land cover and water quality in New York city water supply watersheds," *Environmental Monitoring and Assessment*, vol. 107, pp. 29–44, 2005.