UNIVERSITI PUTRA MALAYSIA

ASSESSMENT OF SHALLOW GROUNDWATER POLLUTION BY POULTRY WASTE IN MINNA, NIGERIA.

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ASSESSMENT OF SHALLOW GROUNDWATER POLLUTION BY POULTRY WASTE IN MINNA, NIGERIA.

By

ADEOYE, PETER ADEREMI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

August 2014

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DEDICATION

This thesis is dedicated to my daughters;

Sylvia Temitope Adesewa and Sandra Tolulope Adedolapo Adeoye.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy.

ASSESSMENT OF SHALLOW GROUNDWATER POLLUTION BY POULTRY WASTE IN MINNA, NIGERIA.

By

ADEOYE PETER ADEREMI

August 2014

Chairman: Associate Professor Hasfalina Che Man, Ph.D

Faculty : Engineering.

A study to estimate the quantity of wastes generated from within some poultry farms in Minna, Niger State, Nigeria was conducted. Similarly, an assessment of management and disposal methods in order to develop sustainable manure management and pollution prevention plan for the purpose of accurate accounting of generation and manure composition was carried out. Effects of poultry waste dump on groundwater in the farms were also assessed using physicochemical and microbiological parameters. Structured questionnaires focusing on farm information, birds' information and waste management were administered to the farm operators and their staffs in the farms. Fresh poultry manure samples were collected from layer, broiler and cockerel sections of three of the selected farms at bird's growth stage of 6 and 12 weeks respectively. The samples were analyzed for nitrates, phosphates, heavy metals and bacteriological parameters.

Findings from the questionnaires showed that a total of 2,131,400 layers, 1,224,840 broilers and 848,570 cockerels which amount to a total of 4,204,810 birds are raised annually in confinement in the farms covering an area of 170 hectares of land. The farms generate 100.97 metric tons of dead birds over a brooding cycle with about 26,565 metric ton of waste excluding slaughter house litter and hatchery wastes. Laboratory analysis results showed that the waste samples contained values as high as 206.75 mg/g and 34.21 mg/g of nitrates and phosphates respectively. Bacteriological values recorded are 25767.21 cfu/100mg, 48214 cfu/100mg and 17647.9 mg/g for faecal coliform, total coliform and *faecal streptococci* respectively. Arsenic concentration in the manure was found to be 37.3mg/g, chromium, 46.2 mg/g, copper, 121 mg/g, zinc, 396.2 mg/g and manganese concentration of 466.3 mg/g. The high heavy metals concentration was suspected to have originated from the addition of some antibiotics to poultry feeds for improved performance as shown in the feed composition. Management of the waste is poor in the farms visited as indiscriminate dumping on land and burning are major waste management systems in these farms. From the assessment, 52 % of the farmers do not treat the waste before dumping on land, 30 % add Aluminium sulphate while 9 % add

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ferric chloride. With respect to dead birds' management, 43 % of the farmers bury them, 30 % re-feed them to animals, 30 % sell to fish farmers while 14 % subject them to burning.

To assess the effect of the poor waste management on Minna shallow aquifers, an assessment of water quality from 20 randomly selected shallow wells inside the poultry farms was carried out. Samples of water were collected from the shallow wells and were analyzed for physical, chemical and bacteriological parameters.

Results showed that the water quality is very poor; highly contaminated with faecal matter. Faecal as high as 348.67 cfu/100ml, total coliform 673.8 cfu/100ml and *faecal streptococci* of 220cfu/100ml were detected in some water samples from the wells. Turbidity and total dissolved solids of 67.4 NTU and 219.3 mg/L respectively were also recorded. For chemical parameters, Nitrate concentration of 232.5 mg/L, phosphate of 29.9 mg/L, arsenic of 0.72mg/L and chromium of 3.21mg/L were also detected in water from the shallow wells. Only 15% of the water samples satisfy WHO guideline value of 0 cfu/100 ml in dry season but reduced to 5 % in the wet season. For total coliform 10% satisfy WHO guideline value in dry season but none of the well sampled was total coliform free in the wet season. About 25 % were free from *faecal streptococci* during the dry season, but only 5 % was free from these bacteria in the wet season. Statistics ($p > 0.05$) show significant difference between coliform values in the wet and dry seasons. Generally the wells are polluted with coliforms which may have probably migrated from poultry waste dumps into the wells. The difference in physical parameter values was also statistically ($p>0.05$) significant between seasons, 55 % of the water samples satisfy WHO 5 NTU turbidity value in the dry season but the value reduced to 30% in the wet season. Lower values were recorded for TDS and EC in the wet season than in the dry season. For chemical tests, 50 % of the water meet up with WHO 50 mg/L nitrate guideline in the dry season and reduced to 35 % in the wet season. Statistics ($p>0.05$) shows no significant difference in the phosphate values for wet and dry seasons. Evaluation of equations generated by Logistic Regression presented a safe lateral distance of 31 meters between poultry manure dumps and shallow wells in Minna to guarantee potable water.

Minna soil, based on findings from lysimetric study is porous and present very small attenuation capacity to poultry wastes contaminants. Phosphates concentration of 12.91mg/L and nitrates concentration of 148.29mg/L contained in poultry manure were able to leach down to 2.5 meters depth of the soil within three months and bacteriological parameters, faecal coliform concentration of 343.89 cfu/100ml and total coliform of 353.84 cfu/100ml were able to migrate down to 2.5 meters in the subsoil of Minna two months after introduction of poultry manure into the experimental set up. Heavy metals (As, Zn, Cr, Cu and Mn) however did not leach beyond 0.5 meters depth of the soil after six months.

Simulation with Visual MODFLOW predicted a five-year reduction in phosphates and nitrates concentration in the aquifer if indiscriminate and over application of poultry manure to Minna soil is checked, though the rate of heavy metal reduction is very small. For instance a reduction in concentration from 253.6 to 78 mg/L is recorded for nitrate, from 29.9 to 21.00 mg/L for phosphates, 0.74 to 0.60 mg/L for arsenic, zinc from 11.63

to 7.51 mg/L and copper from 8.47 to 4.20 mg/L over a five year period. These concentration values are still higher than WHO guideline value for drinking water and this points to the fact that five year period will not be enough for adequate cleaning up of Minna shallow aquifer. Based on findings from this research, it is recommended that an organic fertilizer plant of annual capacity 200,000 metric ton or a biogas production digester of same capacity be developed for Minna. It is also recommended that shallow wells located at a distance below 31m to poultry waste dump be considered unfit for drinking and should be closed up. Water managers should ensure strict compliance with 31m lateral distance whenever any shallow well is being constructed in Minna. More research is also recommended for deep aquifers inside the poultry farms.

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PENILAIAN TERHADAP PENCEMARAN AIR BAWAH TANAH CETEK OLEH SISA PENTERNAKAN AYAM DI MINNA, NIGERIA.

Oleh

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Satu kajian untuk menganggarkan kuantiti sisa-sisa yang terhasil di dalam beberapa ladang penternakan ayam di Minna, negeri Niger, Nigeria telah dilaksanakan. Juga, satu penilaian terhadap pengurusan dan kaedah-kaedah pelupusan bagi membangunkan pengurusan najis dan pelan pencegahan pencemaran yang mampan untuk tujuan pengiraan penghasilan dan komposisi najis yang tepat telah dijalankan. Kesan-kesan pembuangan sisa penternakan ayam ke atas air bawah tanah di ladang juga telah dinilai dengan menggunakan parameter fizikokimia dan mikrobiologi. Soal selidik berstruktur bertumpu kepada maklumat ladang, maklumat ternakan dan pengurusan sisa telah dilakukan ke atas pengendali dan pekerja ladang. Sampel najis segar telah dipungut dari bahagian ayam telur, ayam pedaging dan ayam jantan dari tiga ladang terpilih pada masing-masing 6 dan 12 minggu peringkat tumbesaran ayam. Sampel-sampel telah dianalisis untuk parameter nitrat, fosfat, logam berat dan bakteria.

Hasil daripada soal selidik meunjukkan bahawa sebanyak 2,131,400 ekor ayam telur, 1,224,840 ekor ayam pedaging dan 848,570 ekor ayam jantan dengan jumlah keseluruhan 4,204,810 ekor ayam telah diternak secara tahunan di dalam reban di ladang meliputi kawasan tanah seluas 170 hektar. Daripada pengiraan, ladang-ladang ini menghasilkan 100.97 tan metrik ayam yang telah mati selepas satu kitaran perindukan dengan kira-kira 26,565 tan metrik sisa tidak termasuk sisa-sisa rumah penyembelihan dan penetasan. Keputusan analisis makmal menunjukkan bahawa sampel sisa mengandungi nilai setinggi 206.75 mg/g dan 34.21 mg/g, masing-masing untuk nitrat dan fosfat. Jumlah bakteria telah direkodkan masing-masing sebanyak 25767.21 cfu/100mg, 48214 cfu/100mg dan 17647.9 mg/g untuk koliform fekal, koliform total dan *faecal streptococci*. Kepekatan arsenik di dalam najis didapati sebanyak 37.3 mg/g, kromium, 46.2 mg/g, kuprum, 121 mg/g, zink, 396.2 mg/g dan kepekatan mangan sebanyak 466.3 mg/g. Kepekatan logam berat yang tinggi disyaki berpunca daripada penambahan beberapa antibiotik terhadap makanan ternakan untuk hasil yang dipertingkatkan seperti ditunjukkan dalam komposisi makanan. Pengurusan sisa di ladang yang dilawati adalah lemah dengan pembuangan dan pembakaran tidak terkawal

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menjadi sistem pengurusan sisa utama di ladang-ladang tersebut. Daripada penilaian, 52 % penternak tidak merawat sisa sebelum dibuang ke atas tanah, 30 % menambah Aluminium sulfat manakala 9 % menambah ferric klorida. Mengenai pengurusan ternakan yang mati, 43 % penternak menanam ternakan ke dalam tanah, 30 % memberi makan bangkai ternakan kepada ternakan lain, 30 % menjualnya kepada penternak ikan manakala 14 % membakar bangkai ternakan tersebut.

Untuk menilai kesan pengurusan sisa yang lemah terhadap air bawah tanah di Minna, satu penilaian kualiti air daripada 20 telaga cetek di dalam ladang penternakan ayam yang dipilih secara rambang telah dijalankan. Sampel air telah diambil daripada telaga cetek dan telah dianalisis untuk parameter fizikal, kimia dan bakteria.

Keputusan menunjukkan bahawa kualiti air adalah sangat rendah; tercemar teruk oleh bahan fekal. Koliform fekal setinggi 348.67 cfu/100 ml, koliform total 673.8 cfu/100ml dan *faecal streptococci* sebanyak 220.30 cfu/100ml telah dikesan dalam beberapa sampel air daripada telaga. Kekeruhan dan pepejal terlarut masing-masing sebanyak 67.4 NTU dan 219.3 mg/L juga telah direkodkan. Untuk parameter kimia pula, kepekatan nitrat setinggi 232.5 mg/L, fosfat setinggi 29.9 mg/L, arsenik sebanyak 0.72 mg/L dan kromium sebanyak 3.21 mg/L juga telah dikesan di dalam air daripada telaga cetek. Hanya 15 % daripada sampel air yang memenuhi nilai garis panduan WHO iaitu 0cfu/100 ml dalam musim kering tetapi berkurangan kepada 5 % dalam musim lembap. Untuk koliform total, 10 % memenuhi nilai garis panduan WHO dalam musim kering tetapi tiada satu sampel pun yang bebas koliform total dalam musim lembap. Kira-kira 25 % adalah bebas daripada *faecal streptococci* pada musim kering, tetapi hanya 5 % bebas daripada bakteria tersebut pada musim lembap. Statistik ($p > 0.05$) menunjukkan perbezaan ketara antara nilai koliform pada musim lembap dan musim kering. Secara umumnya telaga-telaga tersebut telah tercemar dengan koliform yang berkemungkinan berpindah dari tempat pembuangan sisa penternakan ke telaga. Perbezaan nilai parameter fizikal juga secara statistiknya ($p>0.05$) ketara antara musim, 55 % sample air menepati nilai kekeruhan 5NTU oleh WHO pada musim kering tetapi nilainya menurun kepada 30 % pada musim lembap. Nilai yang lebih rendah direkodkan untuk TDS dan EC pada musim lembap berbanding pada musim kering. Untuk ujian kimia, 50 % sampel air menepari dengan garis panduan WHO untuk nitrat sebanyak 50 mg/L pada musim kering dan berkurangan kepada 35 % pada musim lembap. Statistik ($p>0.05$) menunjukkan tiada perbezaan ketara untuk nilai fosfat pada musim lembap dan musim kering. Penilaian untuk persamaan dihasilkan daripada Regresi Logistik memberikan jarak lateral selamat sebanyak 31 meter antara kawasan pembuangan najis ternakan dan telaga cetek di Minna bagi menjamin air yang boleh diminum.

Tanah di Minna, berdasarkan keputusan daripada kajian lisimetrik adalah berliang dan mempunyai kapasiti rintangan yang sangat kecil terhadap bahan cemar sisa pertenakan ayam. Kepekatan fosfat sebanyak 12.91 mg/L dan kepekatan nitrat setinggi 148.29 mg/L yang terkandung di dalam najis ternakan telah mengalir turun kepada 2.5 meter kedalaman tanah dalam tempoh tiga bulan dan untuk parameter bakteriologikal, koliform fekal setinggi 343.89 cfu/100ml dan koliform total sebanyak 353.84 cfu/100ml telah mampu untuk bergerak turun ke dalam subtanah di Minna sebanyak 2.5 meter dua bulan selepas pengenalan najis ternakan ke dalam susun atur eksperimen. Logam-logam

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berat (As, Zn, Cr, Cu and Mn) walau bagaimanapun tidak mengalir turun melebihi 0.5 meter kedalaman tanah selepas enam bulan.

Simulasi dengan MODFLOW Visual menjangkakan lima tahun penurunan terhadap kepekatan fosfat dan nitrat dalam akuifer jika aplikasi najis ternakan yang tidak terkawal dan berlebihan ke atas tanah di Minna diperiksa walaupun kadar pengurangan logam berat adalah sangat rendah. Sebagai contoh, penurunan kepekatan daripada 253.6 kepada 78 mg/L direkodkan untuk nitrat, daripada 29.9 kepada 21.00 mg/L untuk fosfat, 0.74 kepada 0.60 mg/L untuk arsenik, zink daripada 11.63 kepada 7.51 mg/L dan kuprum daripada 8.47 kepada 4.20 mg/L dalam jangka masa lima tahun. Nilai-nilai kepekatan ini masih lebih tinggi daripada Tahap Bahan Cemar Maksimum (MCL) dan hal ini menunjukkan fakta bahawa jangka masa lima tahun adalah tidak memadai untuk pembersihan secukupnya akuifer cetek di Minna. Berdasarkan hasil kajian ini, adalah disyorkan supaya sebuah loji baja organik yang mempunyai kapasiti tahunan sebanyak 200,000 tan metrik atau sebuah pencerna untuk penghasilan biogas yang berkapasiti sama dibangunkan untuk Minna. Juga disyorkan supaya telaga cetek yang terletak kurang 31 m berhampiran tempat pembuangan sisa ternakan dikenalpasti sebagai tidak selamat untuk diminum dan harus ditutup. Pengurus air patut memastikan syarat ketat dipatuhi di mana jarak lateral ialah sebanyak 31 m jika ada telaga cetek hendak dibangunkan di Minna. Lebih banyak kajian juga disyorkan untuk akuifer di dalam ladang ternakan di Minna.

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